METALLURGIA

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Metallurgical Education and Training

A NUMBER of investigations have been made in recent years into the technical manpower position in this country—some of them covering industry as a whole and others dealing specifically with the metal industries. Wherever conclusions have been drawn concerning the latter, the view has been taken that insufficient numbers of technologists, of both the best and the good grades, are forthcoming. This is one of the problems considered in the recently published report—The Education and Training of Metallurgists—of the Joint Committee on Metallurgical Education, set up in 1945 by the Councils of The Iron and Steel Institute, The Institution of Mining and Metallurgy, The Institute of British Foundrymen, The Institute of Metals and The Institution of Metallurgists.

The term metallurgist in this report is used in its broadest sense to cover all who are engaged—in whatever capacity—in the winning of metals, in their purification, their alloying or their working. It includes, therefore, both technologists and technicians. The former may be considered to be well informed in the basic sciences and in scientific method, and to possess, in addition, an expert knowledge of the application of metallurgical science in the industrial field, whilst technicians have little knowledge of the basic sciences but are skilled in the expert conduct of some branch of productive work, and comprise, therefore, craftsmen and operatives, together with chargehands and supervisors up to the rank of foreman.

Nothing has emerged from the present survey to change the Committee's opinion that the universities are the chief source of high-grade metallurgical technologists, and that it is doubtful whether any other source of equal value can be developed. It is recommended, therefore, that the university schools of metallurgy expand the output of technologists to the utmost of their ability, and that more university schools provide instruction in industrial science. At the same time, attention is drawn to the value to be gained by providing opportunities for the contact of undergraduates with cultural and humanistic subjects to be expanded, and by introducing courses in management and administration into the curricula.

It is clear, however, that more technologists are needed than the universities can supply. At present, not all the leading positions can be filled by graduates, and those unfilled, together with those of less eminence, demand an increased output of well-qualified men from the colleges of technology. Considerable attention is paid in the report to the ways in which this object can be achieved. In the first place, there must be a clear appreciation of the important differences between the training of technicians and that of technologists, the former being mainly concerned with the "how" of a process or operation, and the latter with the "why." This calls for quite different qualities in the teaching staff and the Committee considers that the average quality of the teachers of technology should be higher than it is now, and that all who teach technological metallurgy should have been trained and become qualified in the theory and practice of the subject. The provision of a good teaching staff is of paramount importance, and by comparison such matters as technological universities, institutions of technology and degrees in technology are relatively unimportant. The upgrading of a few colleges of technology for the production of more high-grade technologists would help in attracting the higher grade of teacher, as would also the opportunity for members of the staff to carry out research work of their own. Perhaps of even greater importance, however, in relation to the quality of technologist turned out, the staff should be sufficiently large to allow of the fairly prolonged absence of one member at a time for the purpose of keeping up to date with industrial progress.

It would be of considerable help to such high-grade colleges if local industrialists would collaborate in devising courses, facilitating the attendance of their employees, and allowing members of their staff to participate in the teaching of suitable subjects, always assuming they have the ability to teach. In the matter of attendance at courses, it is felt that the adoption of sandwich courses would accelerate the output of technologists. This would mean absence from the works for six months of each of, say, four consecutive years, and it is evident that no employer would be likely to agree to such a course unless the employee concerned was of such a type as would be likely to benefit fully.

Those attending courses at technical colleges, whether of the evening, day release or sandwich type are being trained and educated in parallel, but the university student on graduation has been educated but not trained, and it is desirable that formal methods of training graduates immediately they enter industry should be established, so that they can quickly adapt themselves to taking over the responsibilities for which their education and training have fitted them.

One of the outstanding recommendations of the Committee is that the whole of the examinations in metallurgy for non-university students should be rationalised. It believes that corporate membership of one of the professional metallurgical institutions (generally the Institution of Metallurgists) should be the ultimate goal for technological students in metallurgy, and suggests that such changes be made in the requirements of these institutions as would fit their examinations to technological candidates equally with theoretical students. To assist in achieving a proper rationalisation of all examinations, the creation of a Board of Metallurgical Studies and Examinations, to deal with matters

which are not internal to the universities, is recommended.

The educational ladder must rest on firm ground by being based on the needs of operatives and technicians, for whom the City and Guilds of London Institute makes provision. Through the regulations for its grouped course certificate, the City and Guilds Institute extends the ladder a long way, but it is believed that the ladder should lead the best students to the A.I.M. It is considered that the relationships between the requirements of the City and Guilds of London Institute, of the National Certificate Committee, and of the professional institutions could be so ordered and integrated that a youth might sit one examination after another, of increasing difficulty and standard, obtaining one of the lower qualifications at least. The various colleges of technology would thus have a common incentive—the Associateship of the Institution of Metallurgists—as the professional qualification for their best students.

Hot Dip Galvanizers Association Meeting

International Conference Papers Discussed

AT a general meeting of the Hot Dip Galvanizers Association held in London at the end of last month, representatives of leading British general galvanizing firms had an opportunity of discussing papers prepared for the recent International Conference on Hot Dip Galvanizing organised by the Zinc Development Association and held at Düsseldorf. MR. H. T. EATWELL (G. A. Harvey & Co. (London), Ltd.), Chairman of the Association, opened the meeting by referring to the improvements in zinc supplies since the last general meeting early this year. MR. STUBBS (Director of the Zinc Development Association), pointed out that U.K. galvanizers had been hit harder than those anywhere else by the zinc crisis, which had led to severe rationing and the prohibition of many uses of zinc coatings—a policy others had regarded as short-sighted, in view of the waste of steel it entailed: no other country had enforced end-use restrictions on zinc coatings. Mr. Stubbs referred to the comforting news contained in the authoritative Paley Report on U.S. raw material resources, to the effect that unlike other base metals, such as copper and lead, zinc appeared likely to be available for the next 25 years in amounts expected to be adequate to meet the growth in demand with little or no increase in real zinc costs.

Discussing the design of galvanizing baths in a paper entitled "A Galvanizer's Views on Bath Heating," MR. E. MC.I. WILSON (Henry Hope & Sons, Ltd.), emphasized the need for continuous working to reduce costs, and described how the baths should be constructed to allow a faster throughput of work. Because of the greater ease of control, gas was now replacing coke-firing for the heating of the galvanizing baths. In some countries, electrical heating was being used, but the running costs were too high in Britain.

In a paper on "The Economics of Galvanizing," MR. F. C. BRABY (Fredk. Braby & Co., Ltd.), stressed the need for economy now that raw materials and labour costs were so high, and suggested how best the problem could be attacked. He referred to the co-operative work of the Association which had contributed much to a reduction in the output of zinc residues, an economy which had no detrimental effect on the quality of the galvanized product.

MR. R. W. BAILEY (Z.D.A.), in introducing a paper on "Flux Techniques and Hot Galvanizing Economics," by MR. A. T. BALDWIN, one of the four American delegates to the International Conference, referred to MR. BALDWIN's pioneer work on the study of galvanizing fluxes, which had also enabled galvanizers to reduce their metal losses. That kind of scientific research on the fundamentals of galvanizing was very rare 20 years ago, but its value was now generally appreciated throughout the industry.

The galvanizing of cast iron, which was discussed by MR. W. MONTGOMERY (Fredk. Braby & Co., Ltd.), often presents difficulties to the smaller jobbing galvanizers. Mr. Montgomery explained the metallurgical differences between cast iron and steel and showed how, through an understanding of them, the galvanizing problems could be overcome. He thought that mechanical shot blasting was by far the best way of preparing castings for dipping.

MR. A. R. L. CHIVERS (Z.D.A.), in his paper "The Treatment of Pickle Liquors," explained briefly why it was no longer permissible to discharge used pickle liquors direct into sewers or rivers. He described some modern British plants which had been installed by galvanizers to treat waste liquors, and mentioned the possibility that ferric chloride might eventually be used for sewage treatment.

S.A.S.M.U.T.A.

Annual Autumn Conference

THE Annual General Meeting and Autumn Conference of the Sheet and Strip Metal Users' Technical Association will be held at the Grand Hotel, Birmingham, November 6th and 7th, 1952. Following the Annual General Meeting on November 6th, the Conference will be formally inaugurated by the Lord Mayor of Birmingham, Alderman W. P. Bowen, who will also officially open at the same time, the exhibition of sheet metal working equipment and techniques and will then proceed to inspect the exhibits.

In the technical sessions to be held on the afternoon of November 6th and the morning and afternoon of November 7th, papers on "Factors which Influence the Selection of Metal Finishes," "Ultrasonic Testing" and "Materials used in the Manufacture of Press Tools," will be presented for discussion; there will also be a general discussion on "Press Tools for Punching, Blanking and Forming." The technical session on Thursday evening will be devoted to a film lecture on (1) "Multi-Point Welding," and (2) "Automatic Ejection of Pressings," and will take place in the Mason Theatre, University of Birmingham, Edmund Street. A number of works visits have been arranged for members on the Wednesday afternoon.

All technical sessions are open to non-members on payment of a registration fee. Admission is by ticket only; these may be obtained from the Association at 49, Wellington Street, Strand, London, W.C.2.

Tinplate Production in South Wales

New Plant in Operation at Trostre

The highlight of the Special Meeting of the Iron and Steel Institute held in South Wales at the beginning of the month was the visit to the new tinplate works of The Steel Company of Wales at Trostre, near Llanelly, whose operation will have an important bearing on the future of the South Wales tinplate industry. In the following pages a brief description is presented of the plant and processes employed.

FOR many years South Wales has been the home of the British tinplate industry, but until to-day 70% of the tinplate produced in Wales has been made by the old pack mill method, which calls for a high degree of skill in the operators and is slow and costly to operate. Modern experience has shown that the continuous strip mill is superior not only in speed of production, but in uniformity of product and economy of operation, and long before the war it was obvious to all who were engaged in the industry that only the building of a wide continuous strip mill in South Wales could put the industry back on its feet and enable it to maintain its place in the competitive markets of the world.

View of the continuous pickling line.

Although strip rolling for tinplates was developed in the U.S.A. in the middle 1920's, it was not until 1938 that the first continuous strip mill in this country was put into operation at Ebbw Vale, to be followed by a continuous electrolytic tinning line in 1946. At the outbreak of war, in 1939, rolling in strip form had become almost universal in the U.S.A. and developments were also taking place on the Continent. Before that time, most of the plates exported from Britain were hot-mill rolled, but many foreign can-makers, having adjusted their plants for the American cold-rolled plate, acquired a preference for its better stamping qualities. Hence, to be able to compete with America in export trade, it became imperative that strip rolling should quickly supersede the old pack method in this country.

The proposals put forward by the British Iron and Steel Federation after the war included a £60,000,000 project for the South Wales steel and tinplate industry. Because it was considered that the task of reconstruction required was beyond the resources of any individual group, an amalgamation took place between four of the largest firms in the industry, leading to the formation of the Steel Company of Wales. The four firms—Guest Keen Baldwins, Richard Thomas and Baldwins, John Lysaght and the Llanelly Associated Tinplate Companies—pooled certain of their resources calculated at a value of more than £10,000,000 including a steelworks at Port Talbot and Margam, 18 tinplate works in West Wales, and a sheet works at Newport.

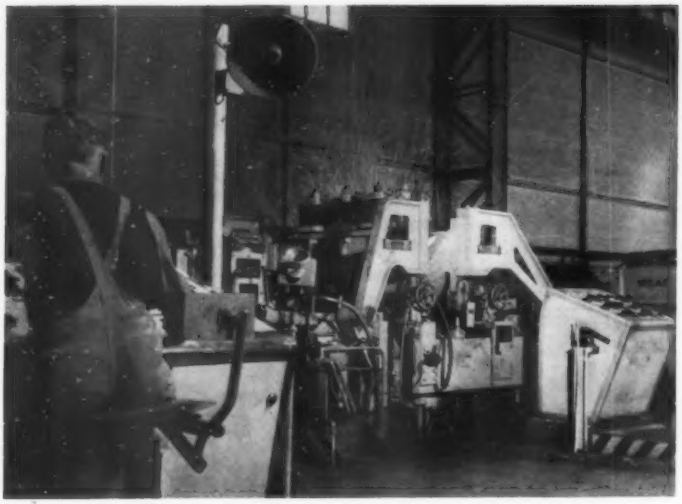
The project involved the reconstruction and enlargement of the blast furnaces, coke ovens and coal and ore handling plant at the Margam steelworks, in order to produce the increased pig iron requirements, and the erection adjacent to the Margam works of a new 80-in. continuous strip mill, together with a melting shop and ancillary plant, making one integrated works which would, when completed, extend for 4½ miles and have an estimated steel output of 1½ million ingot tons per year. As an integral part of the scheme there were to be two cold reduction mills and a modern tinplate plant. One of the cold mills was to be placed alongside the continuous mill at Margam, while the other together with the tinplate plant was scheduled for erection at Trostre, near Llanelly. The Margam extensions were officially opened in July of last year and it is with the Trostre plant, which has been coming into production over the last year or so, that the present article is concerned.

The Trostre plant, which comprises pickling line, tandem cold mill, cleaning line, annealing plant, temper mills, and electrolytic and hot-dip tinning plants, occupies 236 acres of a 420-acre site adjoining the main London–Fishguard railway line.

Construction of the Plant

Construction work commenced in August, 1947, and after the initial clearance of the site, moving farms, hedges, trees, etc., it was necessary to lay an ash carpet over the area to be occupied by the plant. This was done by bringing lorry loads of filling material from surrounding works tips and spreading it to an average depth of 2 ft. over the whole area, which increased the elevation to 16·00 A.O.D. Liverpool.

Next, 26,000 17½-inch diameter concrete piles—all manufactured on site—were driven to an average depth



Automatic welding of coils before pickling.

of 24 ft. There was a certain amount of rock present on the site and, wherever possible, use was made of it. For example, the foundations for the 5-stand tandem cold reduction mill and the temper mills sit directly on the rock.

To ensure safety from floods, and to provide natural drainage, it was decided to raise the mill floor to 28 A.O.D., and since many mechanical and electrical cellars were required, besides various pipe tunnels, large areas between the ground and mill floor are of cellular construction. For the foundations some 170,000 cu. yd. of concrete were used together with about 10,500 tons of steel reinforcement.

Most of the bays are 120 ft. wide × 60 ft. and 50 ft. high, the longest being nearly half a mile in length. Constructed with a high-low type of roof, they give excellent lighting conditions at all levels. Of the 9,000 tons of structural steelwork in the buildings, that above crane girder level has been shot blasted, metallised with aluminium and then resin dipped and painted to ensure added protection against corrosion. The buildings are all brick-clad, for which 5,000,000 bricks were required.

All the foundation bolts for holding down the machinery were set body fast in the concrete, the tolerance permitted being not more than $\frac{1}{16}$ in. in any direction. Every bolt had to be surveyed in separately, and the fact that there were more than 10,000 such bolts, varying from 4 in. to 1 in. in diameter gives some idea of the work involved.

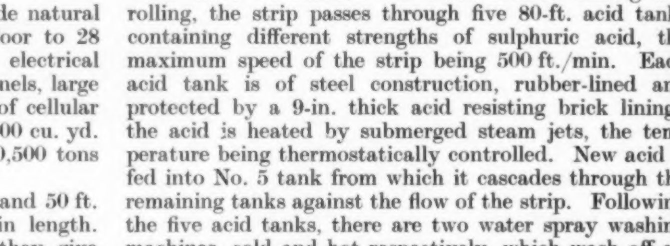
A special beam was designed to enable two overhead cranes to be linked together to lower into position the heavy mill housings, the heaviest of which weighed nearly 100 tons each.

Continuous Pickling Line

Hot-rolled coils from the continuous strip mill at Margam are delivered to Trostre in various steel qualities, as scheduled by the cold reduction plant, the maximum weight of coil being 15,000 lb. and the maximum gauge and width being 0·093 in. and 38 in. respectively. Normally, the coils are transported the 25 miles from Margam by rail in special 42-ton wagons, but road haulage can be quickly organised when required. The coil wagons are berthed directly in the reception bay and the coils are unloaded with Heppenstall type tongs by one of two 25-ton overhead cranes which service the pickling area.

Each coil is loaded on to a conveyor which carries it to an uncoiler at the entry end of the pickling line. As the strip is uncoiled, it is subjected to a reverse bending operation to break up the scale before levelling and passing to the upcut shears where the end of the strip is trimmed. To enable the pickling operation to be continuous, the trailing end of one coil is attached to the leading end of the following coil by flash butt welding or stitching, used alternately. The strip is then fed to pinch rolls into a looping pit, about 12 ft. deep, designed to hold a reserve of strip to allow for the time lag while the welding or stitching takes place. Further pinch rolls draw the strip out of the looping pit and deliver it to the No. 1 acid tank.

In order to remove the scale formed during hot rolling, the strip passes through five 80-ft. acid tanks containing different strengths of sulphuric acid, the maximum speed of the strip being 500 ft./min. Each acid tank is of steel construction, rubber-lined and protected by a 9-in. thick acid resisting brick lining; the acid is heated by submerged steam jets, the temperature being thermostatically controlled. New acid is fed into No. 5 tank from which it cascades through the remaining tanks against the flow of the strip. Following the five acid tanks, there are two water spray washing machines, cold and hot respectively, which wash off all adhering acid and, with the help of steam-heated air,

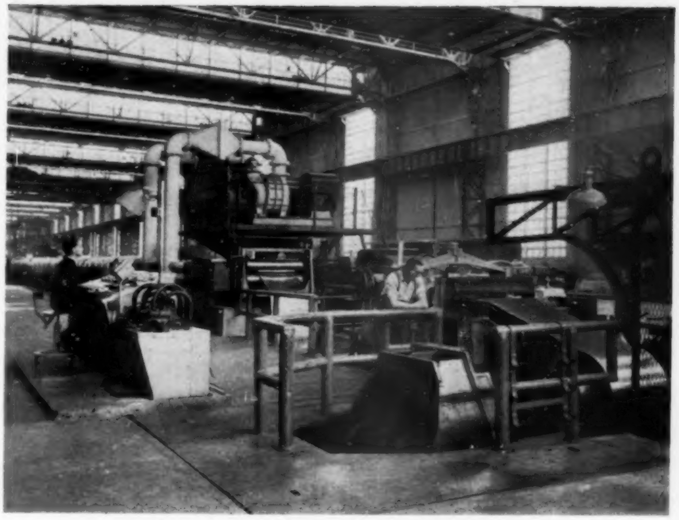


The exit end of the continuous pickling line.

dry the strip. Each tank is provided with a hood to collect the fumes which pass through a rubber lined sewer, and thence through a water spray located in the base of the exhaust stack.

After washing and drying, the strip is fed into a looping pit to form a reservoir to allow for shearing and recoiling of completed coils. Pinch rolls draw the strip from this pit to a shear where the stitched ends of the coils only are cut out. The strip is then side trimmed to remove ragged edges, the trimmings being baled in a scrap baler in the basement prior to returning to Margam as scrap. As the weld is not removed, the strip is recoiled into 30,000-lb. coils, during which process it is coated with hot palm oil, and the coils ejected on to an automatic weigher before being rolled to a storage ramp.

Raw acid storage is provided in four elevated steel tanks outside the main buildings, and provision is made for recovery of the spent pickle liquor.



The exit end of one of the cleaning lines.

Tandem Cold Reduction Mill

The coils are next loaded on to the entry conveyor of the 5-stand cold-reduction mill. This conveyor feeds a rotating rig which, in turn, guides the leading end of the coil into the guides of No. 1 stand, and eventually the coil itself into the coil box where it is paid off into the mill. After passing through the five stands, the strip is reduced to the required gauge, and the leading edge of the strip is engaged in the exit reel and rewound as a 30,000-lb. coil. It is then stripped off and ejected on to a ramp, down which it rolls, being automatically weighed as it passes over the scale. By this process, 10 men can produce 500 tons of strip in an 8-hour shift, or 750 tons in 12 hours, compared with the 6 tons produced by the hand mill in the same time.

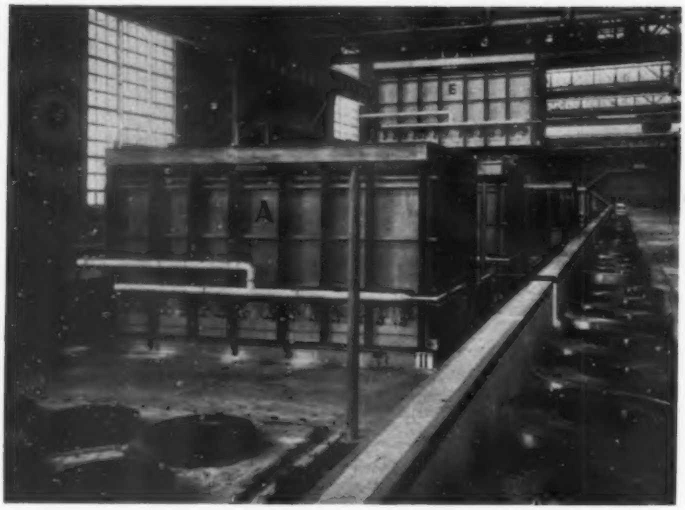
The mill consists of five 4-high stands and a Klein-type tension reeler, together with the necessary driving, screwdown and control equipment. The cast steel housings each weigh in the neighbourhood of 100 tons, and have 53 in. diameter $\times$ 47 in. long back-up rolls, also of cast steel, and forged steel work rolls 21 in. in diameter $\times$ 48 in. long. Each stand is driven by a D.C. motor through a pinion stand, the horse-power of the motors for the successive stands being 1,750, 3,500, 3,500, 4,000 and 5,500, with a 900 h.p. motor for the tension reel. The maximum speed of rolling in the last stand is 4,500 ft./min.

The driving motors for the tandem mill are housed together with their associated motor generator sets in a special room, 160 ft. $\times$ 100 ft. beneath which, in a room of equal size, are the copper connections for these machines and 23 motor-driven fans to supply cooling air to the main motors. In an adjoining room are the contactor boards for this mill, having a total length of over 250 ft., whilst other rooms in this block accommodate switchgear and auxiliary plant. All these rooms are supplied with washed and filtered air at a slight positive pressure to keep out dirt and dust.

The five-stand tandem cold reduction mill.

During the rolling process, the strip is lubricated with palm oil and passes through wood-lined air-operated wiper boxes before entering the nip of the rolls. The rolls are water-sprayed to dissipate the large amount of heat generated during cold reduction, and to control their temperature, the resulting mist being exhausted into a fog-elimination system and discharged by a chimney to the atmosphere. The palm oil and water thus applied collect in the sump at the base of the mill and are run off to a palm-oil recovery system. The palm oil is separated and reclaimed, whilst the water, with a certain amount of palm oil in emulsion, is cooled and recirculated.

Inter-stand tensiometers indicate inter-stand tensions, and during acceleration and retardation the tension is automatically varied; off-gauge material is thus reduced to a minimum. Flying micrometers, which



View of the annealing plant.

are located between stands 1 and 2 and after stand 5, register to 0·001 in.

Electrolytic Cleaning Line

After cold reduction, all traces of palm oil must be removed from the strip, otherwise difficulties would arise in subsequent operations, due to its carbonising during annealing. This cleaning is effected in two electrolytic cleaning lines which operate at a maximum strip speed of 2,000 ft./min.

The 30,000-lb. coils are loaded either by tractor or crane on to a conveyor ramp or on to the coil-charging car at the entry end of the line. They are pushed on to a mandril-type pay-off reel from which the strip is unwound, the leading end of one coil being welded to the trailing end of the previous coil to permit continuous operation.

The strip first passes through a 22 ft. long caustic dip washer tank which removes the bulk of the palm oil. Then, after passing through a scrubber, it enters the main electrolytic tank, which has grids above and below the strip and contains hot caustic solution. Beyond the electrolytic tank is a second scrubber and a 20 ft. hot water rinse tank from which the strip emerges through wringer rolls before entering the hot-air drying sections. A looping pit enables the strip to be rewound in 54 in. diameter coils ready for annealing. These coils, which are about 15,000 lb. in weight, are conveyed to the annealing plant by fork-lift truck.

Annealing Department

In order to obtain a ductile plate, it is necessary to anneal the strip after cold reduction in the tandem mill and this operation is carried out in an oil-fired portable-cover furnace plant which comprises twelve furnace bases and five portable covers, each base having two rows of four pedestals on which the coils are stacked four-high with the axes vertical and ribbed convector plates between the coils. The total charge on each base is, therefore, in the neighbourhood of 200 tons. When loading is completed, a special heat-resisting steel cover is placed over each stack, the bottom being made gas-tight by a sand seal.

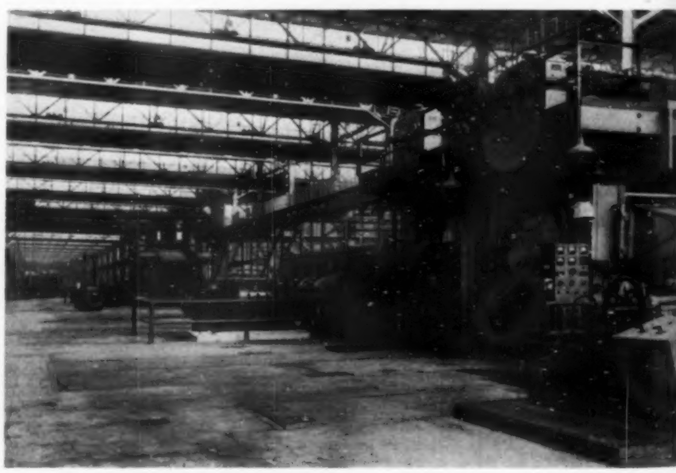
The furnace cover, which is then lowered into position over the charge, consists of a reinforced steel casing, lined with refractory and carrying a row of oil burners at each side and at each end. There are 30 burners per furnace, the flames from which are directed down and around the eight stacks, the temperature of each stack and of the furnace itself being continuously recorded and automatically controlled. During the heating and soaking cycle, to prevent oxidation of the coils, inert NX gas is circulated inside the heat-resisting steel covers by means of centrifugal fans. The NX gas plant is located in a separate building just south of the annealing bay, and consists of three generating units, each capable of generating 12,000 cu. ft. of gas per hour.

Temper Mills

Following annealing, the strip is cold rolled to the required temper. All coils are given a skin pass in one of the two temper mills, the amount of cold work depending on the purpose for which the plate is intended. For deep-drawing material, the temper rolling is sufficient to give only a closed surface for tinning. For can-body stock, the first pair of rolls is shot blasted.

Each temper mill comprises two 4-high stands operating in tandem, the cast steel back-up rolls being 53 in. diameter × 47 in. wide, and the forged steel work rolls 18 in. diameter × 48 in. wide. Morgoil bearings are used for the back-up rolls, and tapered roller bearings for the work rolls. Each stand is powered by a 1,000 h.p. motor and the maximum operating speed of the mills is 4,000 ft./min.

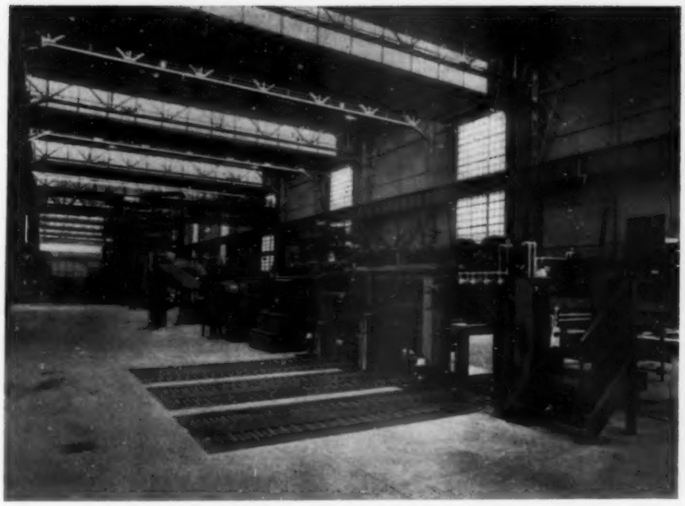
The coils from the annealing furnace are charged on to a drum-type pay-off reel at the entry end, after which the strip passes round a pair of 20-in. diameter top- and bottom-entry tension rolls driven respectively by 500 and 250 h.p. motors, into No. 1 stand. From here it passes over another tension roll into No. 2 stand which is identical with No. 1. On leaving No. 2 stand, the strip



The two-stand tandem temper mills.

passes round a set of exit tension rolls, from where it is automatically engaged on a recoiling mandril. At this point, the maximum weight of the coil is 15,000 lb. and its diameter is about 54 in.

When recoiling is complete, the coil is stripped off the mandril, its subsequent route depending on whether it is to be tinned electrolytically or by hot-dipping.



Exit end of the electrolytic tinning line.

Coil Preparatory Line

Strip which is to be tinned electrolytically is passed through one of two preparatory lines where the edges are side trimmed and the strip is recoiled to ensure a good condition to maintain continuous operation in the subsequent tinning process. Each line is capable of handling and recoiling 30,000-lb. coils, up to maximum width of 38 in., at a maximum speed of 1,800 ft./min. Down-cut shears and a strip welder are incorporated so that coils can be built up to the maximum diameter desired. The speed of the strip through the line is controlled and adjusted by photo-electric cells located in the looping pits.

Shearing Line

When tinning is to be effected by hot-dipping, the operation is carried out on sheets, not strip. Material for this process is, therefore, fed into a shearing line for cutting into sheets. From a drum-type pay-off reel, the strip is fed through a looping pit into a side trimmer which is equipped with rotary knives which are adjustable from 14 in. min., to 38 in. max., the sheared scrap being passed through a chute to the basement for return to the steelworks. The looping pit is equipped with photo-electric cells to ensure speed control between the pay-off reel and the side trimmer. From the side trimmer the strip passes to a second looping pit, similarly controlled to prevent tension, and on through off-gauge and pin-hole detectors. From this stage it is subjected to a roller levelling operation prior to being cut up into sheets by Hallden-type rotary-driven shears. The maximum speed of the shearing line is determined by the length of cut and varies from 650 ft./min. at 18 in. to 1,000 ft./min. on the 37½ in. cut.

The sheared plates then travel along a conveyor to a classifier, where the off-gauge and perforated sheets are automatically stacked in one pile and the primes in another. The prime plates are then taken on stillages to the hot dipping section.

Electrolytic Tinning

The electrolytic tinning of steel strip can be carried out by two main methods, one acid and one alkali. In the acid method, the electrolyte is made up of a solution of stannous sulphate, cresol-sulphonic-acid, free sulphuric acid, gelatin and beta-naphthol. In the alkali method, the electrolyte is a solution of sodium stannate containing small quantities of free caustic soda, sodium acetate and hydrogen peroxide. In both these methods, the amount of tin deposited is controlled by one or more of the following factors: the size of the tin anode; the ratio of the surface areas of cathode and anode; the distance between cathode and anode; the rate of travel of the strip; the density of the bath; and the electric current.

At Trostre, there are two acid Ferrostan lines designed to handle 30,000-lb. coils and to tin ½-lb. coatings at a speed of 800 ft./min. with correspondingly decreased speeds for heavier coatings. Selenium rectifiers supply the necessary direct current up to a maximum of 60,000 amperes at 16 volts. The amperage varies with the speed of the line and the weight of coating being deposited, and is automatically controlled to give a constant weight of coating at constant speed.

Exit end of the coil preparatory line.

There are two uncoilers to aid continuous operation. The leading edge of the coil is sheared and welded to the trailing edge of the preceding coil, time for this operation being provided by two loops held in a 70 ft. deep pit, the length of the strip in the loop being controlled by photo-electric cells fixed near the bottom of the pit. The strip then passes through pin-hole and off-gauge detectors, for automatic ejection at the end of the line, followed by cleaning, which consists of electrolytic degreasing, cold-water rinsing,

electrolytic sulphuric acid pickling, and, finally, spraying with water and brushing.

Next comes the tinning zone, which comprises five plating tanks and one drag-out tank, where the strip is washed and the electrolyte recovered for future use. The strip then passes through a flow-melt unit, where it is electrically heated to allow the tin on the surface to flow evenly; this gives it a bright appearance and improves the quality. It is then sprayed with chromic acid to prevent staining on lacquering and during storage. After drying, the strip is coated with a very thin film of cottonseed oil, which affords the necessary lubrication for subsequent fabricating operations.

The strip is then sheared into plates of required size and classified in a manner similar to that described for the shearing line, except that the classification is also controlled from two visual inspection positions. Any off-gauge or perforated plate that has been detected by a flying micrometer and pin-hole detector earlier in the line is deposited on the first pile, whilst the second pile contains any plate of doubtful appearance, and the third pile prime plate, which is automatically counted and recorded by means of an "electric-eye" counter. Stillages from the first and second piles are re-assorted for recovery or re-treatment, while those from the third pile are bulk-packed for shipment.

Hot Dip Tinning

At present, hot-dip tinning of sheets produced at Trostre is being carried out by the older type plants operated by the Company in the area, but space has been allowed in the layout for this operation to be included, and nine two-path Poole Davis machines are now being installed for the purpose. In this unit, the actual tinning operation will be preceded by an automatic feeder and electrolytic hydrochloric acid pickler and washer.

After cleaning in an Aetna-type cleaning machine, sheets will be delivered simultaneously from each path to a cross conveyor which will transfer the sheets one behind the other to the inspection line, the travel of which will be parallel to the tinpot pass line. At this point an inspector will check every sheet for gauge and quality and classify them into three qualities. By means of push-button electrically controlled deflector gates along the classification line, the inspector will direct the prime plates into a pile at the end of the classifying table, where they will be automatically counted and recorded, and stacked in piles of a known number ready for packing. There will be a second pile for menders and a third for defective plates. The menders from both the electrolytic and the hot-dip tinning lines will be re-tinned in the hot-dip unit.

General Services

Roll Shop.—Mill rolls are prepared in a building conveniently situated adjacent to the cold-reduction and temper mills, roll assemblies being conveyed to this department by means of two electrically driven transfer cars. The equipment includes two roll-grinders, one roll lathe, shot blast equipment, and shear blade grinding machines.

Machine Shop.—This department is centrally situated for servicing the whole plant and contains various machine tools for general plant maintenance work.

Steam and Hot Water Plant.—In a separate building adjacent to the main mill bay there are 10 super economic type boilers fitted with chain grate stockers. These boilers have a working pressure of 150 lb./sq. in. and 100° F. superheat for providing steam for processing purposes and high pressure hot water for heating the buildings.

Administration.—Departmental offices together with laboratories, time-offices, medical, locker and ablution rooms are all of the most modern design. An interesting feature of the plant is the personnel tunnel which extends underground right through the plant with access to each bay by the shortest route.

A New Solder Company

THE old-established firm of H. J. Enthoven & Sons, Ltd., 89, Upper Thames Street, London, E.C.4, has formed a new company which will be operative as from October 15th of this year. Enthovens, one of the leading houses in the smelting and refining of lead and the manufacture of non-ferrous metals, have been engaged in this trade for well over a century. In addition to these activities Enthovens are internationally known in the solder and solder specialities field. The products manufactured by them include such well known brands as "Superspeed," the cored solder with the unique stellate core; "Entocene" Solder Paint; "Zig-Zag," Plumbers' Solder; "Tricene" and "Telecene" Fluxes and a host of others. The rapidly increasing sales, coupled with the infinite variety and ramifications of solders demanded by industry, have made the formation of a new company necessary.

The new company will be known as "Enthoven Solders, Ltd.," who will have their Head Office at Upper Thames Street. It will be divided, for ease of administration and customer service, into two divisions.

One of the divisions, concerned with marketing of solid solders, is to be under the control of Mr. W. J. Myers, who is appointed to the Board of the new company. Mr. Myers has been with Enthovens for 40 years and is, of course, very well known in the industries served by them: he brings a wide experience to the new company. The other is under the direction of Mr. F. C. Thompson, a comparative newcomer to Enthovens, but an executive with great experience in marketing.

The products to be sold are manufactured in a well-appointed, up-to-date factory in Croydon. The well laid-out factory premises include extensive modern laboratories which are staffed with a technical team specialising in the development of solder and the solution of every conceivable type of solder problem. Enthovens are justifiably proud of the unique service which this technical cadre can offer to their customers. It is traditional with Enthovens that their friends in the trade draw heavily on the Enthoven "know-how."

In brief, the new company, whilst being a separate subsidiary, is intimately associated with the parent group, and is eminently able to maintain the high standard set by Enthovens throughout the years.

Metal Powder Agency

THE British Metal Corporation, Ltd., Princes House, 93, Gresham Street, London, E.C.2, has been appointed sole selling agents throughout the world (excepting Great Britain and Australia) for the products of J. & J. Makin (Metals), Ltd., which include electrolytic copper powder, atomised copper, tin, brass and bronze powders.

Sheathing Cable with Aluminium
The Johnson & Phillips' Process

A variety of methods has been suggested for the sheathing of insulated cables with aluminium and in this article is described the process used by Johnson & Phillips, Ltd., details of which have recently been released. The operation, which consists of threading the cable core through an aluminium tube, followed by swaging and sinking, has been in use for commercial production since **1948.**

ALTHOUGH lead has, since the inception of electric power transmission by paper insulated cables, served industry well as the traditional waterproof sheathing material, its well-known disadvantages—principally excessive weight and poor mechanical properties—have for many years encouraged the search for a more suitable sheathing material. The striking advantages of lightness and strength possessed by aluminium make it the most desirable and obvious alternative metal, but its use for cable sheathing has been delayed by the difficulties of application and the relatively high price of aluminium before the war.

Early in 1946, however, a steep rise in the price of lead, together with an acute shortage of that metal, stimulated renewed interest in the use of aluminium as a cable sheathing material. Johnson & Phillips, Ltd. were among the first to examine its possibilities and J. & P. Seamless Aluminium Sheathed Cables—claimed to be the first electric cables in the world to be sheathed with aluminium—have been in commercial production for four years in ever-increasing quantities.

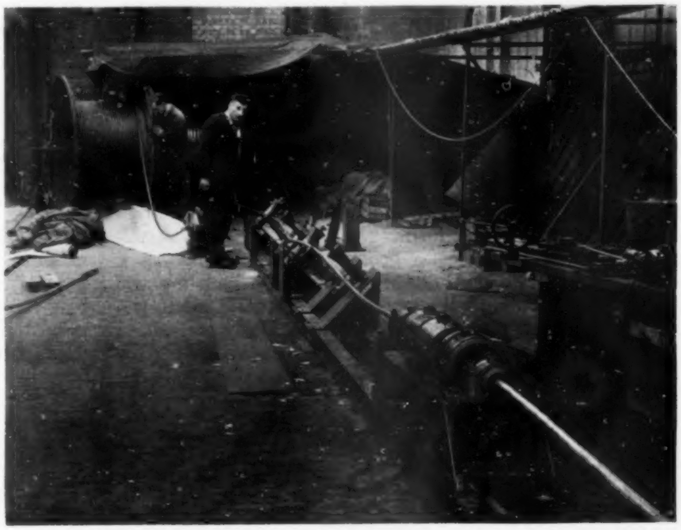


Fig. 1.—Core being drawn into tube on an early experimental plant (May, 1947). For secrecy reasons, this plant was erected each week-end and was dismantled again before the normal working week commenced.

Occasional references to the use of aluminium for cable sheathing date back to the earliest days of insulated electric cable, but it was not until the years immediately before World War II that the subject received really serious consideration. Attempts were then made in Germany to produce an aluminium sheath to meet the need for economic self-sufficiency in the face of internal shortage of lead.

Possible Methods

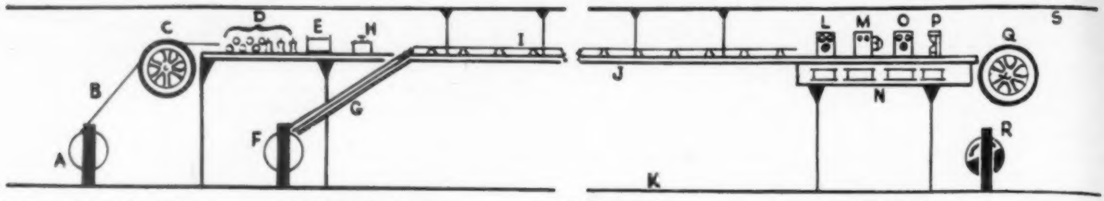
In considering the possibilities of using aluminium as a cable-sheathing material, the Company obtained much useful advice and information from the Aluminium Development Association, and from an article giving a comprehensive survey of the subject which appeared in the September, 1946 issue of *Light Metals*. The Germans had considered two possible methods of manufacture: firstly, an extrusion process similar to that employed for lead; and, secondly, a process whereby helically or longitudinally wrapped strip could be applied to the core and then sealed by welding.

In the absence of the effective welding techniques developed in this country since the war, the scheme for employing seam-welded strip did not succeed in passing beyond a crude experimental stage, and even at its best such a method could not have produced a seamless sheath.

Those favouring the first method—direct extrusion on to the cable core—were faced with a number of formidable problems due to the high softening temperature of aluminium and various other physical characteristics of the metal. In fact, although the Germans had a plentiful supply of soft, super-pure grade aluminium—production of which began in Germany in 1936—only a few kilometres of indifferent quality aluminium sheathed cable were produced. After several years' intensive research and trial, it had been concluded that a specially designed extrusion press would be essential, and there were indications that such a machine had been designed and partly constructed in the early part of the War, but the components had been scattered and damaged during the bombing and invasion of Germany. It was evident, therefore, that no reliance could be placed on the development of a direct extrusion process in time to relieve the lead supply position and, accordingly, J. & P. directed their attention to the only other possible method of producing a seamless sheath—by employing pre-extruded tube.

Use of Preformed Tube

It was visualised that it might be possible—if the necessary lengths of tube could be obtained—to thread a cable core into the tube and, then, by means of a swaging and sinking operation, to produce an accurately fitting sheath. The first experiments in this project took place in November, 1946, at the Kynoch factory of I.C.I., Ltd., who had undertaken to provide aluminium



A Drum of aluminium tube.
B Aluminium tube.
C Guide wheel.
D Straightening rollers.
E Electro-magnet.
F Drum of cable core.
G Ramp to gantry.
H Control unit.
I Troughs.
J Gantry.
K Floor of shop.
L Control unit.
M Swaging machine.
N Hauling gear.
O Control unit.
P Die stand.
Q Hauling capstan.
R Drum for aluminium sheathed cable.
S Roof of shop.

Fig. 2.—Diagrammatic sketch of the J. & P. aluminium sheathing plant illustrating the layout of the principal items. (Not to scale.)

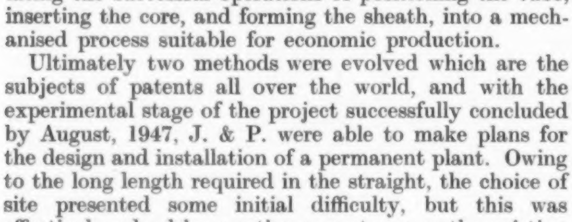
tube in the long lengths required. The samples produced during these experiments enabled much useful information to be gained regarding the characteristics of aluminium sheathed cables and so encouraging were the results that, during the next six months, efforts were concentrated on evolving a procedure capable of translating the successful operations of positioning the tube, inserting the core, and forming the sheath, into a mechanised process suitable for economic production.

Ultimately two methods were evolved which are the subjects of patents all over the world, and with the experimental stage of the project successfully concluded by August, 1947, J. & P. were able to make plans for the design and installation of a permanent plant. Owing to the long length required in the straight, the choice of site presented some initial difficulty, but this was effectively solved by erecting a gantry over the existing plant in a 350-yd. long cable shop, the gantry being supported on the roof trusses. The complete installation of the plant was duly finished in May, 1948, and, just two months later, the first lengths of aluminium-sheathed cable were being manufactured to customer's orders.

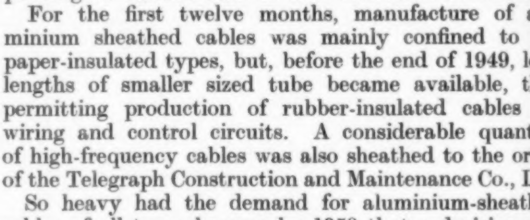
In the meantime, the tube suppliers had developed their technique for extruding long lengths of tube, and many problems associated with testing, handling and packing of various sizes of tube had been overcome.

For the first twelve months, manufacture of aluminium sheathed cables was mainly confined to the paper-insulated types, but, before the end of 1949, long lengths of smaller sized tube became available, thus permitting production of rubber-insulated cables for wiring and control circuits. A considerable quantity of high-frequency cables was also sheathed to the order of the Telegraph Construction and Maintenance Co., Ltd.

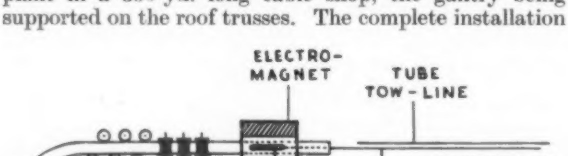
So heavy had the demand for aluminium-sheathed cables of all types become by 1950 that a decision was taken to duplicate the sheathing plant, and, at the same time, to extend its length. This work was completed



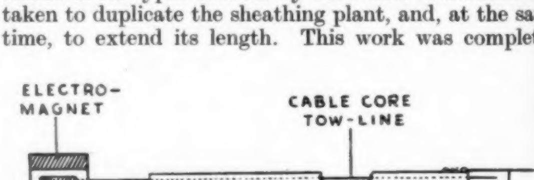
(1) The tube passed through the straightening rollers and electro-magnet, and the steel armature (attached to the cable core tow-line) inserted into the tube within the electro-magnet.



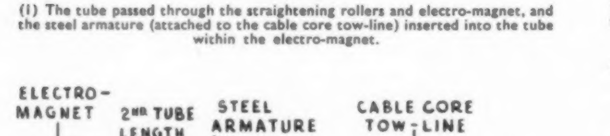
(2) The tube drawn along the main process trough over the cable core tow-line, and the cable core positioned in readiness for the pulling through operation.



(3) The cable core drawn into the tube, and the cable core tow-line returned to the feeding end for the second tube which, meanwhile, has been guided into the electro-magnet.



(4) The swaging of the leading end of the first tube on the cable core, and the second tube connected to the tail end of the first tube. Note the 'additional' core which will ultimately be sheathed due to the extension of the tube in sinking.



(5) The first tube drawn through the sinking dies to form an accurately fitting sheath. During the sinking operation the second tube is drawn along the process trough over the cable core tow-line in the wake of the first tube.

Fig. 3.—Stages in the sheathing process.

by August, 1951, and, up to the present time, Johnson & Phillips have supplied a total of 2,100 miles of aluminium-sheathed cables, this total comprising more than 1,100 miles of paper-insulated cable, nearly 900 miles of rubber-insulated cable, and some 100 miles of various high-frequency type cables. Orders in hand, moreover, will account for upwards of another 500 miles of aluminium-sheathed cable in the near future.

The design and operation of this unique sheathing plant, which is described below, has aroused considerable interest, and several cable companies—both at home and abroad—have adopted the J. & P. process outright, manufacturing aluminium-sheathed cables under licence.

The Johnson & Phillips' Process

The aluminium-sheathing process developed by Johnson & Phillips has been briefly described as the threading of an insulated cable core into a continuous length of oversized pre-extruded aluminium tube which is then sunk down on to the cable to form a seamless close-fitting sheath. Thus outlined, the process appears to be an extremely simple one, but there were many intricate problems to be solved before it could be put on an efficient and economic production basis.

The plant now used extends along the full length of a 350-yd. long cable shop and is installed on a specially constructed gantry erected on the roof supports of the shop. It is so arranged that the intake of the tube and core takes place at one end of the shop (the "feeding end"), and the sheathing and coiling of the cable at the other end (the "sinking end").

For the purpose of this description, the process can be divided into three separate operations, namely: the laying out of the tube (up to 300 yds. in length) in a trough along the plant gantry; the drawing of the cable core into the tube; and, lastly, the drawing of the core and tube through a fixed die and then over a hauling capstan for coiling on to a drum. A diagrammatic sketch illustrating the layout of the principal items is shown in Fig. 2, whilst the component sketches of Fig. 3 show various stages in the process in greater detail.

Laying out the Tube

The long lengths of aluminium tube required are produced in large extrusion presses and are transported to the sheathing plant at Charlton coiled on drums similar to those used for cables. To accomplish the first operation, the aluminium tube is fed from its drum (mounted on a stand at ground level) over a large guide wheel to the plant gantry, where the leading end is guided through a series of rollers which serve to straighten out the tube. Sets of these straightening rollers are provided to suit the various sizes of tube employed. After the leading end of the tube has been passed through the rollers, it is guided through the centre of a solenoid-type electro-magnet and attached to a tow-line which is coupled, at the sinking end of the plant, to the electrically-driven variable-speed hauling capstan. As will be seen later this tow-line is only used when the operation of the process is being initiated, subsequent lengths of tube being towed by the preceding length. Meanwhile, a second tow-line—for the cable core—has been drawn out from a winch at the sinking end in a smaller trough alongside the process trough, and the end of this tow-line is attached to a steel armature which is inserted into the leading end of the aluminium tube lying within the electro-magnet. Thus, when the

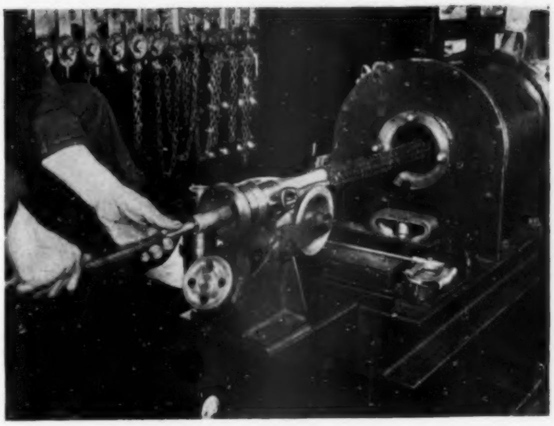


Fig. 4.—Inserting the steel armature (attached to the cable core tow-line) into the aluminium tube lying within the electro-magnet.

electro-magnet is energised, the steel armature is held stationary by the magnetic field whilst the aluminium tube is drawn along the process trough over the core tow-line.

Threading the Cable Core

The cable core is fed from a second drum, also mounted on a stand at ground level, and travels via a ramp to the process trough, entering the gantry through a gap beyond the electro-magnet. The sheathing tube having been towed beyond the gap, the electro-magnet is de-energised and the tow-line lying inside the tube is made fast to the leading end of the core. The winch at the sinking end of the plant is then set in motion and the core is drawn through the tube in readiness for the next and final operation—the sinking of the tube to form the sheath.

However, before the sinking operation is commenced at the far end of the plant, preparations are made for dealing with the next length of core to be sheathed, the

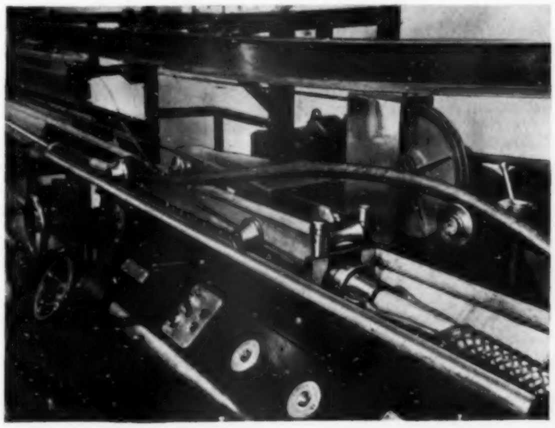


Fig. 5.—A second length of tube connected to the tail end of the first length after the pulling through operation. Note the "additional" length of core purposely left protruding from the first tube, and the core tow-line, the end of which is now being held in the second tube by the electro-magnet.

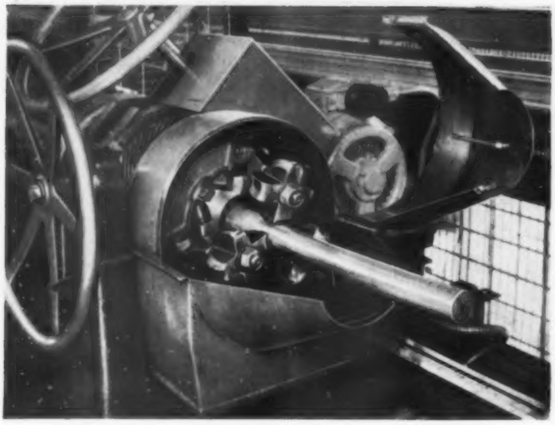


Fig. 6.—The swaging machine, with cowl raised to show the leading 12 in. or so of the tube swaged down on the core.

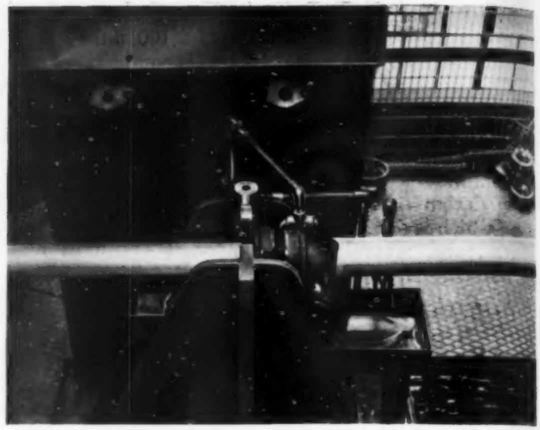


Fig. 7.—The tube being drawn through the sinking dies to form a cable sheath. Note the lubricating oil.

process being semi-continuous in operation. Following the same procedure as described for the first length of tube, the next length of tube is brought up to the plant gantry, passed through the straightening rollers and then through the electro-magnet. The leading end of the second tube length is then connected by means of a special coupler unit to the tail end of the first tube length. The core tow-line, meanwhile, is disconnected from the core at the sinking end of the plant and hauled back to the feeding end (via a third trough extending the length of the plant), where the steel armature is again attached and then inserted into the second tube.

At this stage of the process, a considerable length of cable core is left protruding from the tail end of the leading aluminium tube. This length of core is ultimately sheathed, of course, the effect of the sinking operation being to reduce the tube diameter and, therefore, to increase the length of the tube. The length of sheath produced from 300 yds. of tube can range from 333 yds. to 440 yds., the actual length depending upon the amount of reduction. During the sinking operation, the protruding length of core is normally laid in the trough, but for the larger and heavier sizes of cable, this core is carried on a line of sliding supports which travel along a rail erected above the main trough.

Swaging and Sinking

Having made the necessary preparations for dealing with the second length of tube, the final operation of sinking is commenced. At the sinking end of the plant, the first length of tube (with core inside) is drawn forward into a swaging machine where the leading 12 in. or so are swaged down to enable the tube to enter the two sinking dies and to grip the core tightly. The hauling capstan is then rotated, thus drawing the complete tube through the two dies and forming it into a sheath fitting accurately on to the core. As the sheathed cable emerges from the dies it passes around the hauling capstan for a few turns and then proceeds to ground level where it is drummed, ready for test.

During the sinking operation, the second length of tube is drawn along the plant gantry in the wake of the first tube and, simultaneously, is having its cable core tow-line introduced. When the sinking operation has been completed on the first length of tube, the second length is therefore ready to have its cable core pulled through and the full cycle of the process is thus completed.

The procedure described in the foregoing is followed on successive lengths of tube and core, irrespective of any alteration in size or type of cable, such alterations being accommodated either by a simple die change at the sinking end of the plant or, if the change in size demands it, by selecting a larger or smaller tube and fitting the appropriate set of straightening rollers at the feeding end. The tubes, it may be noted, are manufactured in a standard range of sizes rising in steps of $\frac{1}{8}$ in. up to 1 in. diameter, and in steps of $\frac{1}{4}$ in. above this diameter.

It should be emphasised that although there are two plants, identical in design and installed side by side, they are completely independent of each other in operation. The time taken for each plant to complete a sheathing operation varies somewhat with different types of cable, but a general indication of productive capacity can be given by the average output per plant, which is 3,000 to 4,000 yds. of power cable in a 10-hour shift.

European Steel Production

CRUDE steel production in Europe (excluding the Soviet Union) substantially maintained during the second quarter of this year the record rate attained during the first quarter. This was disclosed in the latest *Quarterly Bulletin of Steel Statistics**.

The publication shows that steel production in the United Kingdom during the second quarter of the year was at the annual rate of 16,360,000 metric tons. During the first quarter of 1952, the *Bulletin* indicates, the production attained the somewhat lower annual rate of 16,244,000 metric tons. During the holiday month of July only, the production rate was 14,466,000 metric tons. It is estimated by the E.C.E. staff that during the second quarter of 1952, Western European crude steel production was at an annual rate of about 61,900,000 metric tons, as against a rate of 62,420,000 metric tons during the first quarter. The slight decline is accounted for by the holiday period, which began in June.

* Available in a bilingual English-French edition from H.M.S.O., Sales Agents for United Nations Publications; 3s. 9d. sterling. Annual subscription (post paid), 15s. sterling.

CO-OPERATIVE RESEARCH ACTIVITIES

Recent years have seen a considerable expansion in co-operative research as carried out by research associations on behalf of a particular industry or group of industries. This is particularly true in the metallurgical field where many of the associations starting in a small way in improvised premises are now settling down in buildings giving greater scope to their activities, and with equipment worthy of the excellent work one has come to expect from them.

There is no doubt that the research associations, whatever the industry they serve, have a most important part to play in the national economy. Now that considerable effort and money must be expended on the rearmament programme, it is more than ever essential that our exports should be competitive in quality and cost—a condition which calls for constant research and development in order to improve products and to reduce costs by achieving greater productivity. Not only is there necessity for economy in the use of labour, but the raw material situation, although showing signs of improvement, is such that every effort must be made to effect economies in the use of certain strategic materials—a factor which is reflected in some of the research work in progress to-day.

There are important differences between research as carried out in the universities and that undertaken in the laboratories of a research association. What is, perhaps, one of the most important of these is the fact that in the latter case there exists a link between the investigator and the people in industry to whom his results are likely to prove of practical value. In this way, the delay between the making of a discovery and its practical application is reduced to a minimum, thus negativing the tendency for so many of this country's scientific discoveries to be ignored until they are applied to industrial processes and materials overseas.

In the following pages are presented brief accounts of certain aspects of the work of a number of research associations in the metallurgical field.

The British Iron and Steel Research Association

The extent of the activities of the British Iron and Steel Research Association can be gauged from the fact that some 400 investigations are currently in progress. Of this total those selected for mention in this review include arc-furnace electrode consumption, heat conservation at the ingot stage, control of strip gauge, coatings on steel and sampling iron castings, while reference is made to a number of international projects in which B.I.S.R.A. is co-operating.

SOME of the more interesting of B.I.S.R.A.'s 400 or so current projects are described here. Many of them relate, as might be expected, to conservation of raw materials, making the best possible use of what is available in a demonstrably imperfect world.

One concerns the use of graphite electrodes in the electric arc steelmaking furnace. Wide variation in electrode consumption has been a source of concern for some time to the makers of steel in electric arc furnaces. This variation was found to occur not only between different plants, but between furnaces at the same plant and sometimes between and within batches of electrodes in the same furnace. The importance of this phenomenon lies in the expense of a high electrode consumption and the loss of production time while broken electrodes are being replaced. There is also the danger of a large piece of carbon falling into the bath during the preparation of a heat of low carbon steel.

When B.I.S.R.A. studied the problem, it was observed that in operation some electrodes became "necked," or reduced in diameter at a particular point, while others showed abnormal reduction in diameter over their whole length. Spectrographic examination eliminated impurity as a cause, but the abnormal wear of an electrode collar was found to be associated with a high electrical resistivity at the weak point. X-ray examination suggests that this is due, in part, to incomplete graphitisation. In addition, the combustion rates of all forms of carbon increase rapidly with temperatures up to 1,100° C., and the explanation for the different rates of wear may be connected with the fact that jointing nipples give a preferential path for the current through the collar, doubling the current density and increasing the heating effect fourfold. If at the same time the resistivity of the material of the collar is double the normal value, the heating effect will be eight times what it would be in the body of a normal electrode.

Two types of resistivity test are now applied to complete electrodes as a routine matter in many plants: (1) the standard method of measuring low resistances, i.e., by measuring the potential fall over a given length of the specimen when a current passes; (2) the core loss comparator test, which has the advantage over the standard method in that it can measure resistance in localised areas. Savings of between four and five shillings per ton of steel have been made in some works by the adoption of these tests.

Ingots—Heat Saving

Research into the problem of heat losses from ingots before stripping has led to some promising results. In the soaking pits, where the ingots are held after stripping from their moulds until they are of even temperature throughout, wide variation in fuel consumption was

found between 18 works surveyed. Though the average was 17 therms per ton of steel, the range was from 10 to 29 therms. There is clearly a wide field for economy here, especially as a stripped ingot may already contain enough heat for rolling, even if unevenly distributed.

A first step is to discover the optimum stripping time for ingots and to present the findings in a form that can be easily used in the works. Theoretical and practical work in close collaboration with member firms has made it possible for the first time to plot the heat loss of typical ingots before stripping. This is related to the time since teeming and the mould temperature before teeming begins, the latter depending on the interval since the mould was last stripped of an ingot. A simple graph has been evolved for works use, to give operatives their best time for stripping.

Control of Strip Gauge

Loadmeters, originally developed by B.I.S.R.A. to measure the separating force in rolling mills, are now being put to a new use, which may help to solve the problem of automatic gauge control in strip rolling. The human eye and hand cannot normally give the necessary control in a high speed cold rolling mill; strip tends to get thinner as rolling gets faster, and thicker as the mill slows down. As a mill may take 10 to 15 seconds to accelerate to the usual operating speed of over 2,000 feet per minute and 5 to 10 seconds to stop, the amount of off-gauge strip at the end of each coil can be considerable. In fact, it may amount to as much as 5% of the total production of a continuous cold rolling mill. A pilot plant to exercise automatic gauge control has been installed on a four-stand cold reduction mill at the Shotton works of Messrs. John Summers & Sons, Ltd. Loadmeters control a regulator which increases or decreases the tension on the strip. For any particular setting, a constant load value will ensure a constant thickness in the rolled strip.

Coatings

Another example of a raw material which has to be expended with economy is zinc. Aluminium, widely examined as a possible substitute, has some disadvantages. It is corrosion resistant and of good appearance, but it does not perform well in the hot dip process; the bath has to be hotter than a zinc one, and a hard and brittle alloy layer of iron and aluminium is liable to form, with a low ductility. It also causes a skin to form in the bath which is difficult and unpleasant to remove, and which can be caught up by the dipped steel. Two years' work at B.I.S.R.A.'s laboratories in South Wales indicate that the problem is well on the way to solution. The work has been concentrated on the preparation of the steel surface up to the moment of dipping, and a pilot plant in Swansea is operating a process which is ripe for industrial development. An aluminium coating would cost less than half a zinc coating of the same thickness, and might in time mean a considerable saving in the cost of producing coated sheets.

Sampling Large Iron Castings

A project of a somewhat different nature has been concerned with the sampling and analysis of large iron castings. Investigations, in which several member firms' laboratories collaborated, established first that derivation of the combined carbon by difference, following separate determinations of total and graphitic carbons was better than the direct procedures investigated. Second, systematic trials were made to determine how representative samples could best be taken. The results showed that none of the accepted methods was really satisfactory, neither milling nor drilling giving reproducible results, even when the proportionate weighing principle was used. Although good results were obtained when small diameter drills were used at low speeds and the whole of the material was used as the analytical sample, it became clear that solid samples were by far the most consistent. A suitable and economical way of obtaining them was found to be by use of a hollow mill of the normal type specified in B.S. 122 of 1938—Milling Cutters and Reamers.

International Projects

In the international field, B.I.S.R.A. has, for the past two years, played a major part in the four-nation flame radiation research trials at Ijmuiden, Holland. The experiments are carried out on a furnace made available by the Royal Netherlands Steelworks, and the ultimate object is to find out everything possible about the mechanism of flame radiation, so that furnace designers and engineers can gain the maximum value from their fuel. Interim conclusions on the behaviour of oil fired flames have been of immediate practical value to designers concerned with the same kind of flame as that used in the tests.

Work on oil-burner design has shown that the effects of varying the quantities of atomising agents are more important than the differences between burners. The great importance of mixing and jet momentum have been demonstrated; it seems probable that designs can be worked out to give the same jet momentum with less steam consumption than at present, and further trials are planned for the end of this year.

The Association also represents Great Britain on a seven-nation committee sponsoring the erection and trials of a low shaft blast furnace at Liège, which will come into operation before the end of the year. The experiments will aim at finding out how far this technique can be used to solve the problems posed by the low grade and crumbly ores, such as those of Lorraine, which have to be used now; the world-wide shortage of good coking coals will also be examined by this international committee.

Other Activities

Some other aspects of the Association's work are illustrated by the publication of the following books during the year, in addition to the usual large number of reports both open and restricted: "Surface Defects in Ingots and their Products—Standard Definitions" (Iron and Steel Institute); "Instrumentation of Open-Hearth Furnaces" (Allen and Unwin); "Magnetic and Electrical Methods of Non-Destructive Testing" (Allen and Unwin); "The All-Basic Open Hearth Furnace" (Iron and Steel Institute); "Polarised Light in Metallography" (Butterworth Scientific Publications); "The Fight Against Rust" (B.I.S.R.A.).

The specification for heavy duty electric overhead travelling cranes, published by B.I.S.R.A. in 1950, has now been revised in the light of operating experience and the amendments are available free of charge from the Association's Information Section, 11, Park Lane, London, W.1.

The British Welding Research Association

By K. Winterton, Ph.D., B.Sc., A.I.M.
Chief Ferrous Metallurgist

The new Fatigue Testing Laboratory at the Abington Station of the British Welding Research Association will give a fresh impetus to the Association's engineering researches on welded construction. Reference is made in this article to the progress made during the last 12 months in both engineering research and metallurgical investigations in the field of light alloys and in that of structural steels.

THE opening by Lord Woolton, Lord President of the Council, on June 23rd last, of the new Fatigue Testing Laboratory of the British Welding Research Association, at Abington, was the culmination of many years' work and planning. This new laboratory has a floor area of 5,000 square feet, and represents a very welcome addition to the laboratory space for the Association's engineering researches in general, since it will house the whole of the work now being undertaken on fatigue testing.

The building itself is of technical interest, since it is the first building to be erected in which the plastic design method originated by Professor J. F. Baker, Professor of Mechanical Sciences in the University of Cambridge, has been applied. Very appreciable economies in steel have been effected by this means, but, as will be seen from the illustration in Fig. 1, this has been done without detriment to an aesthetically pleasing design, the laboratory being roomy, well-lit and ideally adapted for the work.

Fig. 1.—New Fatigue Laboratory at Abington (south aspect).

New Fatigue Testing Machines

An extensive programme of investigations has been planned for the new laboratory, and a good deal of this work is already under way. Due partly to restrictions of space, work on fatigue testing has, in the past, been carried out using the method of resonance vibration for the application of load, and this has imposed limits on the sizes of the machines and test specimens. The Association has recently acquired two non-resonating machines of 100 tons capacity, these being installed in the new building. The Losenhausen machine, illustrated in Fig. 2, with mechanical and hydraulic activation, works at speeds of 100 to 600 cycles per minute, and is capable of static, tensile, bending or compressive loading up to a maximum of 200 tons, or tensile or compressive fatigue loading up to a maximum of 100 tons. The other machine was designed by Professor W. M. Wilson of the University of Illinois, and is operated by means of an eccentric and a load-multiplying lever. Two specimens may be tested independently and simultaneously in this machine, but only at 100 cycles per minute. In addition, a machine for testing pressure vessels and pipeline components is available, and consists of a large capacity hydraulic pump, together with automatic variable gear designed to apply pressure pulsations from atmospheric to 6,000 lb./sq. in. at up to 100 cycles per minute.

Though there may be more extensive laboratories in this country devoted to routine fatigue testing, there is no doubt that the new fatigue laboratory at Abington provides unique facilities for testing full-scale structures, and for investigations involving the fatigue strength of materials or structures, whenever work of a special or unusual character is being attempted.

Other New Equipment

Other new equipment has been obtained during the year, which has enhanced the value of the work in hand in the Metallurgical Section, and which has facilitated general progress. As an instance of this, the Association was fortunate to acquire a short time ago apparatus for the inert gas-shielded consumable electrode type of welding process—an Aircomatic set made by the Air Reduction Company, U.S.A. This is now available at the metallurgical laboratories of the London premises. Much pioneer work has been done by the Association during the past year on similar equipment made in the laboratory, but the acquisition of a commercial set has given a great impetus to the work. A good deal of interest was aroused when the set was used to make the first welded aluminium-alloy deckhouse for a river launch, the welding being carried out by this Association in conjunction with the Aluminium Development Association. Valuable welding experience was obtained during the work.

Facilities are being provided within the metallurgical laboratories for chemical analysis of a routine nature, and also for special applications. A Spekker absorptiometer is now ready for use, and should make possible speedier routine analysis. Equipment is being built for gas analysis, and in particular for the measurement of

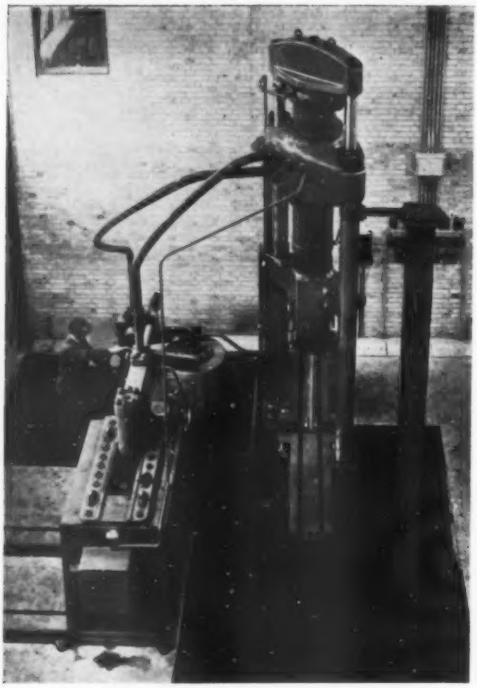


Fig. 2.—The Losenhausen fatigue tester—200 tons capacity.

total hydrogen content. These new facilities were made available, in particular, for the researches on the welding of mild and alloy steels, but the requirements of the light alloy section have by no means been neglected.

The Liaison and Development Service continues to perform a useful function, and during the year under review some 300 enquiries or requests for technical assistance have been received, and over 300 visits made to member and non-member firms. A smaller, though still important rôle, is played by the Library, devoted mainly to welding literature, but which includes an auxiliary library of films and lantern slides.

The Association's Summer School of Welding at Ashorne Hill has proved so popular that it has now become an annual event. In July, 1952, a somewhat longer course was arranged than for the previous year, and over 70 lectures were delivered. The first part of the course was instructional, and arranged for welders and foremen, while the second part was more technical, and divided into specialised groups to meet the needs of designers, metallurgists and those following allied vocations. The school was a great success, with 276 students attending. In view of this, provisional arrangements have been made for a similar function next year.

Metallurgical Research

Constitution Mild Steel Weld Metal.

Over the past few years, investigations have been made into the mechanical properties, particularly ductility, of mild steel weld metal at high temperatures, in an attempt to throw some light on the elusive problem of hot cracking. This fundamental approach is the basis of an extension to the work, in which apparatus is being constructed for the measurement of mechanical properties of weld metal at high temperatures *in an atmosphere of hydrogen.* Under these conditions hydrogen should pass into solution in the metal, and the experiments should give an indication of its effect on the high temperature properties. In addition, the new facilities for special and routine chemical analyses will provide the means for a broadly based investigation into the effect of compositional variations on hot cracking.

A test for hot cracking developed by the Association—the double-fillet test—has been given trials at several firms in this country and also in Holland. Though already of proved value as a research tool, there is still some doubt as to its value in the wider application necessary for a workshop test. Further simplification has therefore been suggested, and a few more industrial trials will be made before a final decision is taken. The preliminary experiments have been made for an investigation to measure the force exerted by a contracting weld, using a dynamometer.

Higher Strength Weldable Structural Steels.

Two steel compositions have been selected after a careful study of the results obtained on a series of nickel-chromium-molybdenum low-alloy steels. These two steels have been the subject of further investigation, and weldability and mechanical tests have been made on them after fabrication in the form of two-ton pilot casts. On an experimental scale, the effect has been investigated of small variations in composition around these two preferred analyses, with the prime purpose of deriving data on acceptable limits for steelmaking practice. So far the results have established the overriding influence of small variations in carbon content. Encouraging results have been obtained from a series of steels of similar composition in which molybdenum is replaced by vanadium.

Fig. 3.—View of welding head—controlled arc process.

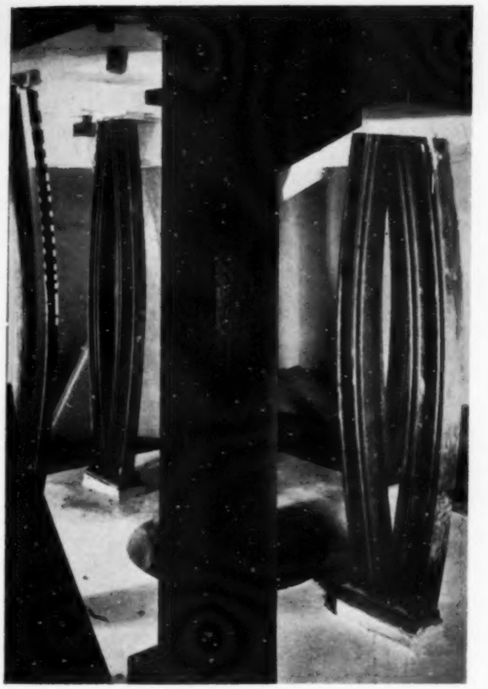


Fig. 4.—Testing pit for Losenhausen machine.

The new weldability test with graded thermal severity (C.T.S. test), reports of which have been pubished recently in *Welding Research*, has been incorporated in the final draft of a British Standard specification for electrodes used in the welding of low-alloy structural steels.

Fusion Welding of Light Alloys.

A good deal of attention has been given during the past year to the development of the newer welding processes for light alloys, employing gas-shielded consumable bare electrodes, i.e. the self-adjusting arc and controlled arc processes, equipment for which has been constructed in the laboratories. Commercial Aircomatic equipment has been received from the U.S.A. through the agency of the Ministry of Supply, and this acquisition will greatly expedite investigations on the subject.

The controlled arc equipment differs somewhat from that of the self-adjusting arc, bare wire being fed through the welding head at a controlled speed, automatically regulated by arc voltage to maintain the arc length constant. The welding head for this apparatus is illustrated in Fig. 3. This system offers some advantages over that of the self-adjusting arc apparatus, and is being used particularly for researches on the welding of magnesium-rich alloys.

Investigations are in progress to determine the fundamental arc characteristics of these new processes by oscillographic and high-speed photographic methods, this work being carried out in collaboration with the Electrical Research Association's laboratories. Another investigation is aimed at minimising weld porosity in the self-adjusting arc process. The materials which are being examined include aluminium–5% magnesium and also some of the higher strength aluminium alloys, a good deal of attention also being given to the magnesium-zirconium alloys—Z.W.1 and Z.W.3.

It has been shown that, using coated electrodes and conventional metal-arc welding, strengths of 17 tons/sq. in. can be obtained on aluminium–5% magnesium sheet. Arising from this, electrode manufacturers are now developing improved aluminium-alloy electrodes in co-operation with the Ministry of Supply and the Association.

Engineering and other Researches

Load Carrying Capacity of Frame Structures.

A stage has now been reached in the work where single and multi-bay Portal frames may be designed more easily and rationally by the plastic theory than by other means, the resulting designs showing considerable economies in the use of steel. The use of the method in connection with the new laboratory at Abington has already been mentioned.

A good deal of interest has been shown in the new design methods, both in this country and overseas, and some applications have been found for service requirements. Published papers are making this knowledge more generally available, and a paper was presented at the fourth Congress of the International Association for Bridge and Structural Engineers at Cambridge in August, 1952. The application of the plastic theory to structures of greater complexity than single-storey frames is rather difficult, but a method of analysis has been developed, and this is described in a paper published in the April *Proceedings* (Part III) *of the Institution of Civil Engineers.*

Tests on simply-supported beams of 7 in. × 4 in. R.S.J. should yield results which will form the basis for assessing the behaviour of the Portal frames. Analysis of the test results is not yet complete, but calculations already made indicate that the collapse load of the pitched roof frames was within 4% of the value predicted by the plastic theory.

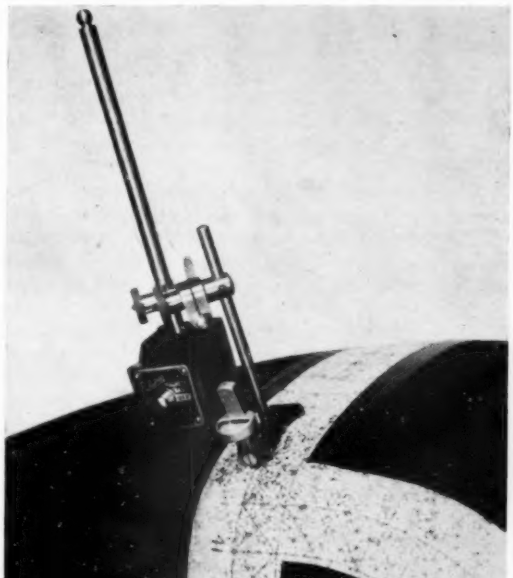


Fig. 5.—New attachment for stress-probing measurements.

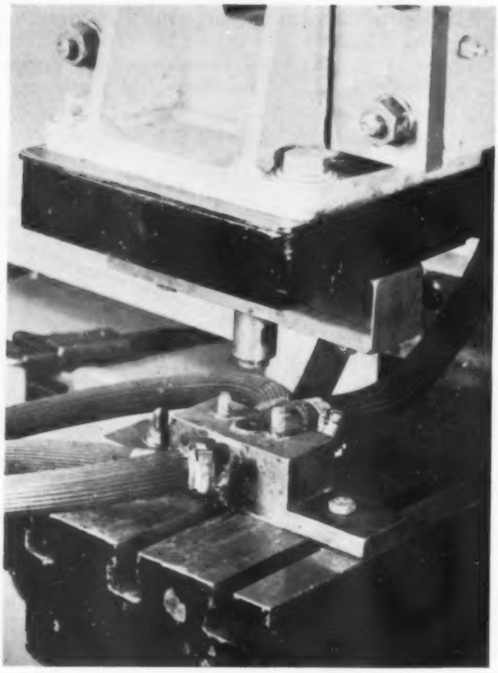


Fig. 6.—Stud welding equipment.

Behaviour of Welded Structures under Dynamic Loading.

To find the effects of some common weld faults on the fatigue strength of mild steel butt welds, a broadly based investigation is planned which forms a natural extension of some exploratory work carried out at the Naval Construction Research Establishment, Rosyth. Initial tests are already under way, using the Losenhausen machine. The general view of this machine in operation, shown in Fig. 2, gives some indication of the testing capacity. The testing pit is situated vertically below the machine, the cover-plate for which may be seen in the photograph. A view of the interior of the testing pit is shown in Fig. 4, and this illustrates the simple method of support which has been employed using pairs of collapsed struts in compression : this method of support was developed by T. S. Robertson of the Admiralty. In addition, a programme of work is planned to study the fatigue behaviour of welded magnesium-alloy plate, using the Losenhausen machine.

In a programme of work on high-tensile steel bridge members, about 30 specimens have been tested to failure in push-pull fatigue tests. The original programme, now nearing completion, had as its objective the comparison of two welding techniques on the fatigue behaviour of fillet-welded joints in bridge members, these two techniques using different metallurgical conditions in the heat-affected zone. The work is to be extended to a different type of specimen, in which the condition of the heat-affected zone might exercise a more profound influence on the fatigue strength of the fillet welds.

A series of *ad hoc* tests to compare the fatigue strength of welded mild steel and welded magnesium-alloy cruciform structures has been completed. These structures were built from channel sections, and were tested under alternating loads applied in a direction at right angles to the plane of the structure, the maximum bending moment occurring at the inter section of the cruciform. Trials were made with several different designs for the intersection joint in the magnesium-alloy specimens. To obtain more accurate data on the service loads to which these cruciforms would be subjected when used in a vehicle structure, bending and torsion moments also have been measured dynamically with wire resistance strain gauges and a ten-channel cathode-ray oscillograph unit. The vehicle tests travel on normal and rough roads and on a severe " suspension " course.

Testing of Welded Pipes and Pressure Vessels.

Apart from the pulsating pressure plant of large capacity mentioned earlier, the original equipment is still available and in constant use. Tests on butt welded pipeline have been used to compare two different welding methods. Four out of six gas-welded specimens failed at a point away from the welded joint, the remaining two having withstood several million cycles without failure. Comparable arc-welded specimens have also been tested to failure, and in five out of six of these the fractures occurred at notches on the inside of the welds. The fatigue life of each specimen was appreciably below the endurance figures obtained with the four gas-welded specimens. Alternating bending tests on gas-welded pipes have shown a reduction of fatigue strength in comparison with unwelded pipe. It is intended to continue this programme of work by an examination of the effect of weld faults in pipe joints, these faults being simulated by artificial discontinuities.

A very complete survey was made of the stresses present in a welded pressure vessel with three branch connections. The findings were illuminating, and resulted in recommended modifications to the design. This is now being followed by the determination of the stress systems in nozzles and compensating plates. It is expected that this will establish data for the most commonly used type of reinforcement. These present investigations have been based to a large extent on the results of the original studies made by Babcock & Wilcox, Ltd. Their final report is now available to members of the Association.

Initial experiments are in progress on 8-in. diameter seamless welding tees, and one of these fittings has been tested to failure under internal pulsating pressure. Similar specimens have been subjected to static pressure tests, and in a third series of experiments an 8-in. tee is being investigated under external loads applied to the branch tube.

Stress probing—the new method which has been developed to obtain rapid stress surveys on vessels subjected to pulsating pressure—has been reported in several technical publications. A recent modification to the technique is illustrated in Fig. 5. To avoid small irregularities due to variations of pressure when the gauge is applied by hand, it is held in place by a spring-loaded arm, attached by a magnetic clamp to the test specimen. The spring-loaded arm is so designed that readings at many positions can be taken without moving the magnet.

Projection, Spot and Stud Welding.

The spot welding of certain aluminium alloys of the Duralumin type has merited considerable attention during the past year, and the analysis of the spot welding data obtained is now virtually complete ; moreover, the investigations on multi-projection welding and spot welding of mild steel have made good progress.

The work on projection welding of steels has led to tentative standard designs for projection welded bolts and suitable welding conditions for attaching such bolts to the sheet material. The investigation has covered bolts of $\frac{5}{16}$ in., 0 B.A. and 2 B.A. sizes attached to 12 and 20 s.w.g. sheet. Over 6,000 welds were made during the test series, and it is believed with some confidence that the design and welding conditions should be suitable under production conditions. A view of the equipment is shown in Fig. 6.

The production of a simple and robust workshop instrument to record current and load simultaneously on a time base has for some time been an important objective; good progress has been made in the design and construction of a suitable instrument. A new principle is used in this unit, the load being measured by a fluid-filled pressure diaphragm and Bourdon tube, while the current is measured by a D.C. energised moving coil operating in the self-magnetic field produced round the secondary conductor.

More fundamental investigations in the spot welding of ferrous materials include an examination of the effect of steel quality on spot welding and the determination, by both theoretical and experimental means, of the distribution of temperature during the spot welding cycle.

Distortion in Welded Work

Institute of Welding Presidential Address

FOR his Presidential Address, delivered at a meeting of the Institute of Welding on October 8th, the incomig President, Mr. A. Robert Jenkins, J.P., A.I.Mech.E., chose the subject of distortion in welded work. He said that comparatively little had been written on this subject, probably because so many variables affecting distortion were encountered in shop practice and technique; these variables gave rise to very mixed results which made it extremely difficult to arrive at a common basis on which to fix reliable rules. Mr. Jenkins mentioned the following ten variables which he said were among those which had to be considered in relation to this problem :—

(1) Type of material and thickness.
(2) Method of preparation of plate edges.
(3) Design.
(4) Amount of restraint on plates during welding.
(5) Accuracy of set-up.
(6) Type of electrode.
(7) Size of electrode and current.
(8) Rate of deposit.
(9) Number of runs.
(10) Manual or automatic welding.

Distortion was produced by shrinkage, the degree of which could be affected by all the variables mentioned. Shrinkage was the residual contraction in volume of the metal after cooling, and distortion ensued if the temperature distribution had not been uniform, as was the case with arc welding.

Mr. Jenkins said he proposed to give the results of shop tests designed to show the extent of transverse and longitudinal shrinkage, and then to discuss practical methods of preventing and reducing distortion, of counteracting it when it had occurred, and of controlling it by staying and strutting; finally he would describe how welded vessels, which through accidents had been distorted almost beyond repair, were made usable again by special treatment.

The results were then shown of a number of tests for distortion carried out by manual arc welding with electrodes of various gauges, on a $\frac{1}{2}$ in. thick plate with V-preparation; these tests showed that a greater degree of *longitudinal* distortion occurred when larger electrodes and higher currents were used, even when the plate was welded from the ends to the centre, a practice which is supposed to reduce distortion. On the other hand, according to examples cited by Mr. Jenkins, a greater degree of *transverse* distortion, was to be expected where small electrodes were used with a greater number of runs. As transverse distortion was the more troublesome, it was the practice to make the weld with the minimum number of runs and at the maximum speed.

Referring to methods for the control of distortion, the President mentioned four ways of minimising it. The first was to make initial allowances, to be added to the drawing dimensions, during the preparation of plates and Mr. Jenkins suggested some figures for this which were based on practical experience in the construction of tanks and cylinders. Another method was to use a sequence of welding which balanced the contractional stresses, while a third was to ensure that plates were carefully prepared for welding, so that large gaps were not left in the joints. Fourthly, regarding transverse distortion, Mr. Jenkins again stressed the advantages of using large gauge electrodes and high currents with a consequent reduction of the welding time.

Where distortion had already occurred it could be corrected, as it had been caused, by local heat treatment for which an oxy-acetylene flame was used. Various examples were shown of this method which must, however, be very carefully applied if it is not to result in fresh distortion.

Restricting the movement of the plate during welding was one method of preventing distortion and Mr. Jenkins illustrated how this could be carried out, where, for example, flanges were to be welded on to two identical objects. It was first necessary to tack-weld the flanges into position, after which the two objects were clamped back to back with packing between them. Welding was then completed and the clamps broken after cooling. The President showed slides illustrating the various ways in which this principle could be applied to prevent the movement of the plate during welding and said that in every case where it was used the edges after welding had remained perfectly straight. Other methods illustrated by Mr. Jenkins were the use of stays and struts to maintain shape during welding, and the pre-setting of parts before welding, the former being particularly valuable in the case of welded tanks.

In conclusion the President showed slides of a number of welded vessels which had undergone accidents in service and described the methods by which the resulting distortion had been corrected.

Two Laboratory Furnaces for Melting Titanium Alloys*

By J. A. Rees†, B.Sc., and R. J. L. Eborall‡, M.A.

(*Contribution from the British Non-Ferrous Metals Research Association*)

The work of the British Non-Ferrous Metals Research Association is exemplified by the following account of the construction of two laboratory melting furnaces (vacuum vertical graphite-resistor type and arc type, respectively). In our last issue, a paper describing the Association's work on derivative polarography appeared in the Laboratory Methods Supplement.

THE British Non-Ferrous Metals Research Association, at the instance of the Ministry of Supply, has been studying the mechanical properties of titanium-base alloys. Techniques have been developed for the preparation of hot rolled strips from ingots made by powder metallurgy methods or by melting and casting *in vacuo*. The strips have been tested for resistance to oxidation and scaling at elevated temperatures, for tensile properties at room temperature and for resistance to creep at elevated temperatures up to about 600° C. Extensive American work has shown that the mechanical properties of titanium and titanium-base alloys are markedly dependent on their contents of oxygen, nitrogen, etc., and that these elements are readily absorbed when the materials are heated to high temperatures. Nevertheless the materials can be hot worked in air with ease, and apparently without incurring undue contamination with these elements, and some of the hot rolled alloys tested in the Association's work show promise for parts highly stressed in service at moderately elevated temperatures.

Fig. 1.—Vertical graphite-resistor furnace.

Owing to the reactivity of the metal and its alloys it was necessary to use special furnaces for melting.

The Vertical Graphite-Resistor Furnace

Early in 1948, in the course of this work, the need arose for a vacuum furnace for the melting and casting of titanium and its alloys involving temperatures around 1,800° C., which could also be used for general high-temperature applications.

The merits of a vertical graphite-resistor furnace, based on a type developed at the United States Bureau of Mines by W. J. Kroll and his associates, were considered. This type of furnace appeared to offer an ease of construction, robustness and efficiency at least comparable with a high-frequency melting unit. As it was intended to melt titanium in graphite pots, the presence of the graphite resistor was not a disadvantage. The Association's high-frequency generating unit was already in daily use and so the resistor furnace was finally selected for construction.

Description of Furnace

The furnace is illustrated in Fig. 1. It is also shown diagrammatically in Fig. 2 and further detail is illustrated in Figs. 3 and 4.

The heating element *A* (see Fig. 2) consists of a graphite tube, 9 in. long, 3½ in. outside diameter, and with a wall thickness of 1 cm. The tube is split from the base to within 2 in. of the top. Each side of the split is supported in a "C"-shaped water-cooled copper segment *B* and electrical contact is made by copper plating the bottom end of the tube and soft soldering each half to its respective segment. Two hollow electrical conductors *C*, which also act as cooling water leads, are brazed to each segment. These conductors pass through the base-plate *D*, to which they are attached and from which they are insulated by neoprene washers and rings which also effect a vacuum seal. To avoid undue inductive heating of the base plate, this is made of brass.

The vacuum-tight furnace cover consists of a cylindrical metal casing *H* with a top plate *J*. The cover is water-cooled and contains three cylindrical metal

* *B.N.F.M.R.A. Report* R.R.A. 974P. Based on confidential reports in *B.N.F. Review*, March, 1951 and July, 1952.

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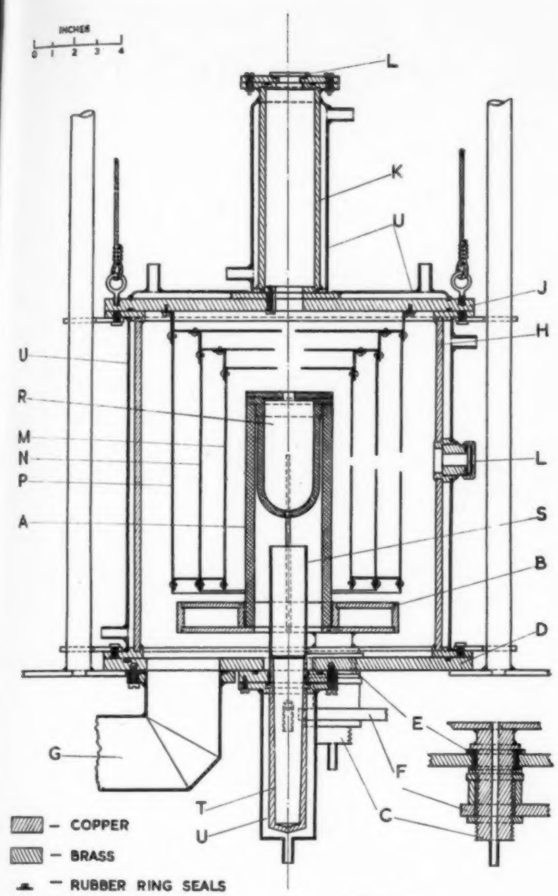


A GRAPHITE RESISTOR
B "C" SEGMENTS
C ELECTRICAL CONDUCTORS
D BASE
E NEOPRENE
F BUS BARS
G VACUUM ORIFICE
H CASING
J TOP PLATE
K EXTENSION
L SILICA WINDOW
M MOLYBDENUM SCREEN
N NICKEL SCREEN
P STAINLESS STEEL SCREEN
R GRAPHITE MELTING POT
S ALUMINA GUARD TUBE
T MOULD
U WATER JACKET

Fig. 2.—Sectional elevation of the graphite-resistor furnace.

radiation screens, *M*, *N* and *P*. It will be noted that the use of refractory materials is kept to a minimum in the construction of this furnace, as such materials usually evolve large volumes of vapours on heating and so cause deterioration of vacuum conditions. The window *L* on the extension *K* allows observation of the melt through holes in the three screens. The cover is counterbalanced so that it can easily be raised or lowered.

Vacuum Seals

All vacuum seals are made by means of trapped dry rubber rings, the form of the joint for flange connections being similar to one which had proved successful in the Association's electron diffraction camera. The rubber rings are made from round-sectioned pure indiarubber cord of 0·16 in. diameter and are held in grooves of the shape shown in Fig. 4.

As the cross-sectional area of the groove is slightly larger than that of the ring, the flanges may be bolted up hard. In the case of the seal between the furnace cover and the base plate no bolts are required as the atmospheric pressure is more than sufficient to tighten the joint.

Pumping System

The furnace is evacuated through a 3 in. diameter orifice *G* in the base plate. The pumping unit consists of two 2 in. mercury diffusion pumps (working in parallel) which are backed by a rotary oil pump. Liquid air and phosphorus pentoxide traps are situated between the furnace and the mercury pumps and between the mercury pumps and the backing pump, respectively. Pressure is indicated by a Philips ionisation gauge and Geisler tubes.

Power Supply

The power is provided through a transformer with nine primary tappings so that from about 5 to 22 kW are available at secondary voltages varying between 4 and 8 volts. Connection is made to the conductors *C* by copper bus-bars and flexible copper leads.

Use of the Furnace for Melting Titanium

The graphite melting pot *R* used for the titanium work has a broad rim, from which the pot is suspended inside the heating element. There is a $\frac{3}{16}$ in. hole drilled in the rounded or pointed base of the pot which is normally filled with a titanium plug. Owing to the temperature gradient produced by the water cooling at the bottom of the resistor, the plug is the last to melt. The metal then pours into a water-cooled copper mould *T* (6 in. long, $1\frac{1}{4}$ in. diameter at the top tapering to 1 in. diameter at the bottom) which is bolted on to the base-plate. Because of the wetting of graphite by molten titanium and the high surface tension of the metal, the last few drops remain clinging to the base of the pot, thus blocking the hole for the next charge.

Fig. 3.—Furnace with casing raised, showing graphite resistor standing on copper segments. In foreground: graphite melting pot and cover, titanium ingot, and rolled titanium strip.

A 300 g. charge of titanium can be melted in about 10 min. although normally the metal is allowed to degas at temperatures between 1,200–1,500° C. for about half-an-hour before melting. When the furnace is cold, pressures of the order of 10^{-4} mm. of mercury (as measured by the Philips gauge) are readily attained, whilst at 1,700–1,800° C. this figure rises to $3 \cdot 5 \times 10^{-3}$ mm. Including the time required for initial pumping down and cooling of the empty pot to a little above room temperature, the total time for a normal melting cycle is about 1½ hr.

Since the completion of the furnace many charges (250–300 g. each) of titanium or titanium alloys have been successfully melted and cast for rolling or forging. During this period, the apparatus has given very little trouble apart from deterioration of the radiation shields. The ¼ mm. thick molybdenum screen *M* became embrittled and distorted after about 50 heats, its reflectivity was greatly reduced and the efficiency of the furnace impaired. It was replaced by a ½ mm. screen and no trouble has since been experienced. The split graphite resistor has proved to be very robust and its efficiency does not appear to have been impaired by prolonged use.

The Arc-Melting Furnace

The graphite-resistor furnace described above proved very successful for melting titanium alloys and general purposes. However, the use of a graphite crucible results in a pick-up of 0·5–1% of carbon, and in order to investigate the effect of purity on titanium and its alloys another melting method was necessary. An arc furnace suitable for melting high-melting-point reactive metals without contamination was built for this purpose.

Titanium reacts with all known refractories, so no crucible can be used if it is desired to maintain high purity. Arc melting in an argon atmosphere successfully avoids this difficulty. The usual method is to pass the arc from a water-cooled tungsten electrode (negative) to the titanium alloy charge which rests on a water-cooled copper hearth connected to the positive current lead. The product is then a small round button of metal.

The present furnace was designed for the production of rectangular bars up to at least 2 lb. in weight (1½ in. × 2 in. × at least 8 in.). There appeared to be two possibilities: to melt a long flat bar on its side, or to build up a vertical bar by adding successive layers as in semi-continuous casting. The latter method was adopted but the furnace was so constructed that by a simple change of hearth plate and mould the other method could be used if necessary. Since other developments, such as true semi-continuous casting, might be desirable later, the furnace was made in a number of separate demountable parts which could be changed if required.

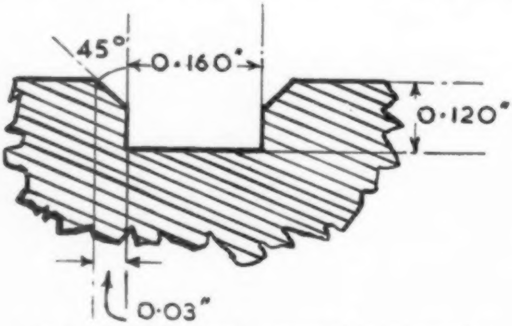


Fig. 4.—Section through groove of vacuum seal.


Fig. 5.—Laboratory arc-melting furnace.

A view of the apparatus is shown in Fig. 5 and the furnace is illustrated diagramatically in Fig. 6. Further detail is shown in Figs. 7 and 8.

Construction of Furnace (See Fig. 6)

(*a*) *Upper Part.*

This consists of a furnace bell *F* with observation windows and an electrode assembly, the whole being counterpoised so that it can be easily raised or lowered.

The electrode assembly comprises a replaceable ¼ in. diameter tungsten electrode *A* brazed into a copper disc, clamped as shown in Fig. 8 into an electrode holder *B*. The latter passes out of the furnace through the metal bellows *D* (Fig. 6) and is controlled by handlebars *C*, which also serve as water connections. When the furnace is in operation the atmospheric pressure on the assembly is counterpoised; at other times the assembly is clamped. The furnace bell *F* is provided with three 4 in. diameter silica windows *G*. It is made from a large copper tube and is water-cooled by means of a copper tube soft-soldered to its outside surface.

(*b*) *Lower Part.*

This consists of (*a*) a fixed section *H* which holds the hearth plate *M*, mould walls *J* and the vacuum pipe *K*, and (*b*) a free section *L*, which can be raised or lowered to facilitate ingot removal if necessary.

The mould is in two parts: the walls *J*, which are attached to the hearth plate, and a movable base *N*, which is a sliding fit between the walls. Both are water-cooled and are fabricated from copper plate by silver soldering. The base is supported by two concentric tubes *O*, carrying the cooling water. These pass out through a Wilson seal *Q* in the base plate *P* and are

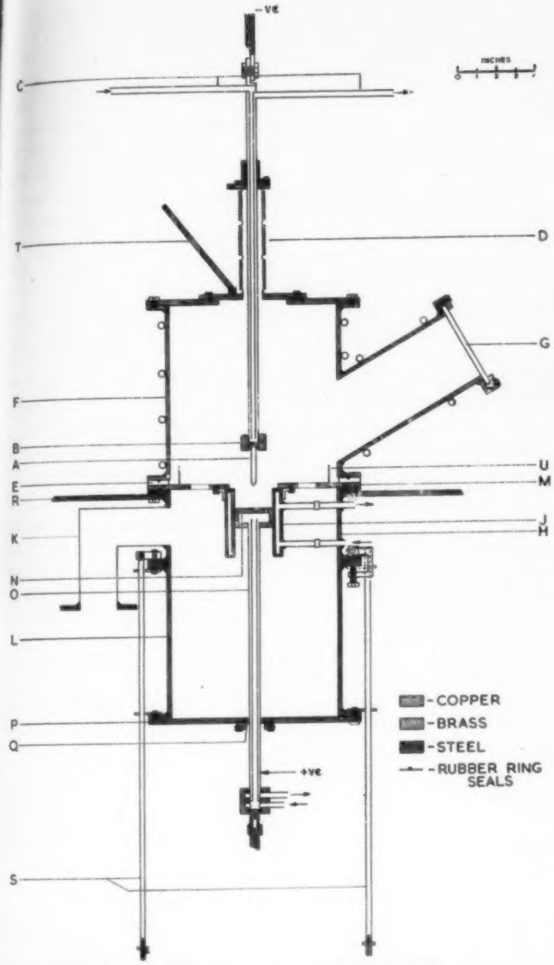


Fig. 6.—Diagram of the arc-melting furnace.

joined at the bottom to a screw-jack which enables the mould base to be moved vertically. It has been found necessary to plate the outer tube to prevent failure of the Wilson seal through interaction between the copper and the synthetic rubber of the seal washer.

The hearth plate *M* and the top flange of the fixed section *H* are bolted together and are supported by the table top *R*. The free section is clamped by swing bolts to the bottom flange of *H* and guide rods *S* are provided to facilitate the lowering and raising of the free section.

Vacuum Seals

The vacuum seals, apart from the top flexible bellows and the bottom Wilson seal, are all made by means of rubber rings (as described above in the case of the resistor furnace). For the seal between the top bell and the fixed section no bolts are required, as the atmospheric pressure is sufficient to tighten the joint.

Fig. 7.—Hearth of arc-melting furnace, with "getter" button in position, and pieces for remelting arranged around hearth.

Pumping System and Argon Supply

The furnace is evacuated through the pipe *K*, via a phosphorus pentoxide trap and shut-off valve, by an oil-sealed rotary mechanical pump of 150 l./min. capacity. Pressure is indicated by a capsule-type dial gauge (0–760 mm. of mercury) and a Geisler tube. An argon inlet with a separate shut off valve is provided. Welding-quality argon is supplied from a cylinder with a pressure regulator, and is purified in the apparatus as described later.

Power Supply

The power supply is a Metropolitan-Vickers D.C. welding generator with a variable 0–400 ampere current range. The mould is made positive and the tungsten electrode negative. The bell is insulated from the base plate by a $\frac{1}{4}$ in. thick Tufnol ring *E* which also carries the groove for the rubber ring seal between it and the

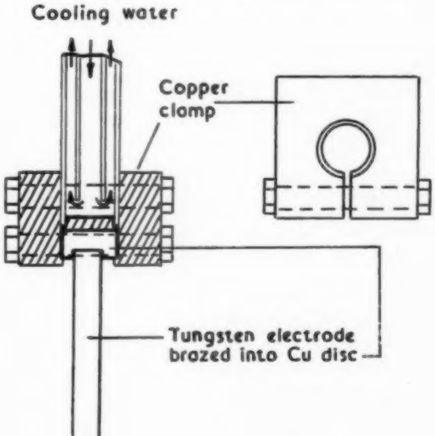


Fig. 8.—Electrode assembly.

bell. The Tufnol ring is screened from direct radiation by a loose metal ring U visible in Fig. 7.

Melting of Titanium

The method employed is to melt successive layers of such a thickness that the whole of each layer can be fused with a little of the underlying layer, so that a sound ingot can be built up. Each layer must have the correct composition, so the procedure adopted is to make a sufficient number of separate 20 g. compacts under light pressure, each consisting of titanium sponge with the right quantity of alloying elements (generally in massive form) pressed in.

In the procedure at first adopted and still in use for unalloyed titanium, the compacts are arranged round the hearth plate and a piece of scrap titanium (to act as a "getter") is placed on the mould base. The furnace is evacuated to a pressure at which the Geisler tube is extinguished (approximately 5×10^{-3} mm. of mercury). Argon is then admitted to a pressure of about 500 mm. and then pumped out again to flush the furnace, and the furnace is finally filled with argon to a pressure of 400 mm. of mercury.

The "getter" is then melted and purifies the argon by absorbing nitrogen and any other gaseous impurities. However, not all the gas is purified since impurities from remote parts take some time to diffuse to the hearth. Gettering is therefore repeated twice after five minute intervals. Finally the getter is pushed off the mould base with the electrode (power off), and the compacts comprising the charge proper are successively placed in the mould and melted, the mould base being lowered as required.

It is envisaged that the compacts may eventually be fed in from a magazine.

The speed of melting is limited by the gassing of the charge and the necessity to ensure mixing. The former can be reduced by previously vacuum baking the titanium sponge or compacts, but the latter necessitates a comparatively long melting time and the original practice with alloy melts was to spend five minutes melting each layer, corresponding to a rate of building up the ingot of about one in. per hour. With this procedure it was sometimes found that mixing was imperfect with certain alloys, resulting in banded structures in the rolled strip. Alloy compacts have since been melted individually before they were used to make the larger bars, and with this modification no trouble has been encountered.

The increase in hardness of a titanium sample due to contamination during melting is negligible. For example, a small sample of sponge titanium when melted had a hardness of 183 V.P.N. (mean of eleven readings); on remelting, the hardness was found to be 186 V.P.N. (mean of six) and on remelting a second time, 183 V.P.N. (mean of four). The "getter" button is found to increase in hardness by about 5 points each time it is used.

Since completion of the furnace, about 80 charges (varying from 20 to 400 g.) of titanium and its alloys have been melted, and no major trouble has been experienced.

Acknowledgments

The authors thank the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish this paper.

Changes in Iron and Steel Prices

THE Minister of Supply has made an Order, which came into force on October 13th, increasing the maximum price of certain types of pig iron and reducing the maximum price of certain steel tubes.

It is the practice of the steel industry to import iron ore from overseas in bulk through the B.I.S.C. (Ore), Ltd., which acts collectively on behalf of the iron and steel companies. Since 1950, this imported ore has been resold to consumers at prices which have not been raised despite the large increases in world ore prices and in freight charges. The resulting deficiency has been recovered by means of a voluntary levy paid by steel makers (whether they use home ore or imported ore) in proportion to the tonnage of steel they produce. This levy is reckoned as a production cost and is reflected in current steel prices. This arrangement has created an artificially low price for imported iron ore. By increasing the price of pig iron, this Order will enable the pig iron makers to be charged prices for imported ore more nearly approaching the true cost of purchase and transportation.

The effect will be to increase the production cost of certain iron castings which are, for the most part, not subject to price control. On the other hand the increased price which steel makers will have to pay for pig iron will be offset by a decrease in the tonnage levy on steel production (referred to above) so that no increase in steel prices will be necessary. In fact the opportunity is being taken to reduce the maximum prices for most types of hot finished steel tubes as shown below. The changes are made in agreement with the Iron and Steel Corporation of Great Britain.

Examples of the increase in pig iron prices are :—

	Old Basic Price Per ton £ s. d.	New Basic Price Per ton £ s. d.
Basic Pig Iron	12 10 0	13 19 0
Hematite Pig Iron	13 11 6	16 2 0
Low Phosphorous Foundry Pig Iron (other than Staffordshire)	13 17 6	16 8 0
Scotch Foundry Pig Iron	14 4 6	15 19 6
Cylinder and Refined Iron	17 4 6	17 14 6
Refined Malleable Pig Iron	17 14 6	18 14 6
Cold Blast Pig Iron (over 3·5% carbon)	18 17 0	19 6 6
Other qualities Cold Blast Pig Iron	no change	
Other qualities Foundry and Forge Pig Iron	no change	

Over 60% of the pig iron used by the iron foundry industry is unaffected by these price changes.

The Order has the effect of reducing the prices of butt welded gas list tubes by between 28s. and 33s. per ton, and of hot finished seamless and lap welded tubes over $6\frac{5}{8}$ in. outside diameter by between 10s. and 25s. per ton according to quality.

Copies of the Order, the Iron and Steel Prices (No. 3) Order, 1952, may be obtained from H.M. Stationery Office or through any bookseller.

The New Laboratories of the British Ceramic Research Association

By A. E. Dodd, Ph.D., M. Sc., F.R.I.C.

Head of the Information Department

The opening by the Duke of Edinburgh, at the end of last year, of the new laboratories of the British Ceramic Research Association, was an important event in the Association's history. In the course of the following brief description of the laboratories, mention is made of some of the work in progress, with particular reference to that appertaining to the metallurgical industries.

WHAT was probably the first proposal for co-operative research was made in the Potteries almost two centuries ago by the first Josiah Wedgwood. Too far ahead of its time, the proposal came to nothing, but with the formation of the Department of Scientific and Industrial Research during the First World War the ceramic industry was again encouraged to take steps to develop its technical and scientific side.

Rear view of the new laboratories.

In a time of war, it was almost inevitable that the branch of the ceramic industry essential to any war effort—the refractories branch—should be the first to form a research association. Refractory products are used in this country to the extent of nearly two million tons a year for the linings of blast furnaces, steel furnaces, plant in the non-ferrous metals industry, gas retorts, coke-ovens, boilers, glass-making furnaces, pottery kilns and all installations that operate at very high temperatures. The British Refractories Research Association, under the direction of the late Dr. Mellor, was formed in 1920 to study these materials and their use. The British Pottery Research Association was formed in 1937. At this time the B.R.R.A. had laboratory accommodation at Howard Place, Shelton, Stoke-on-Trent, and the B.P.R.A. acquired premises and land in Queen's Road, Penkhull, Stoke-on-Trent. In April, 1948, the British Ceramic Research Association was formed by the fusion of the two older Associations, and steps were taken for the building of new laboratories that would provide facilities for a staff able to cover the field of research that now had to be tackled.

Laboratory for the determination of thermal expansion and other physical properties.

A site adjoining Queen's Road, Penkhull, Stoke-on-Trent, was chosen for the new laboratories. The position is reasonably central to the whole of the North Staffordshire Potteries, and sufficiently extensive for foreseeable needs. Towards the end of the summer of 1950 the administrative sections moved into their new offices, and later in the the year the laboratories themselves were occupied.

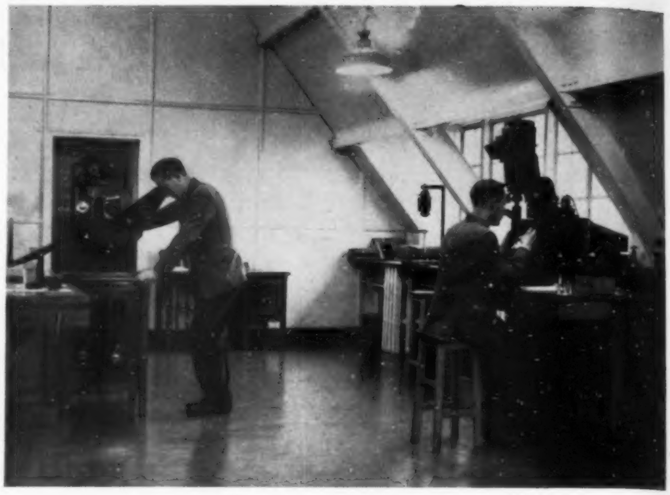
Opening by H.R.H. The Duke of Edinburgh, K.G.

The laboratories were officially opened by H.R.H. The Duke of Edinburgh, on December 12th, 1951. In his address to the assembled Council and other representatives of the industry, the Duke said that he was convinced that it is only by the rapid and continuous application of scientific research

to industry that Britain can hope to pay its way in an increasingly competitive world. He pointed out that the ceramic industry is made up of a few large firms and many small ones, too small to undertake research on their own; co-operative research by a research association is ideally suited to meet just such a situation.

The Ground Floor

The frontage of the building blends the tradition of brickwork with a modern use of octagonal columns in a central stone entrance; the rear of the building has central and flanking wings to give maximum space and light. The main doors open into a central hall, the walls of which are faced with faience having a satin finish. Across the hall from the main entrance doors is a large Council Chamber and Lecture Hall capable of seating 200; this is used for full meetings of the Council of the Research Association and for lecture purposes. At the one end of the ground floor are the Director's and administrative offices; at the other end is the Library and Information Department. The Library is a particularly fine room with ample shelf space for the 8,000 bound volumes and the 50,000 pamphlets which it contains; a comprehensive card index to technical and scientific information on the ceramic industry and related sciences is housed in an adjacent room.



Laboratory for microscopic examination.

The First and Second Floors

The first and second floors of the new building are divided into laboratories fitted out for general or specialised research. X-ray and electron microscope equipment, each with its own dark-room accommodation, are installed on the second floor, which also has mineralogical, rheological and photographic departments. There is a well-appointed chemical laboratory on the first floor; other rooms at this level are used for research for the pottery industry on earthenware, electrical porcelain, bone china, floor and wall tiles, and sanitary ware, and for the refractories industry on fireclay, silica and basic refractories, especially as used in the iron and steel industry, the gas industry and the pottery industry.

Research on Refractories

Some of the work carried out for the iron and steel industry has been described in previous articles in *Metallurgia*. Amongst that now in progress may be mentioned the properties of carbon refractories in relation to their use in blast furnace hearths, and the mechanism of the disintegration of certain fireclay refractories in blast furnace gas; the electron microscope is proving useful in the study of the latter problem, since it permits the growth of the deposited carbon to be followed at an extremely high magnification.

Research has continued on the thermal properties of refractory materials; this has included measurements of the thermal conductivity of refractory insulating bricks, both as units and as furnace walls, and of refractory insulating materials as manufactured and after various periods of service in furnace structures. The information furnished by these investigations will be of help in the design and the assessment of the thermal performance of industrial furnaces.

Small electric furnaces for the firing of test-pieces and ware have been built by the Instrument Section in a large room in the basement; the Instrument Section itself has a workshop at this level equipped to construct apparatus for the use of the research staff. The stores are also located in the basement.

An interesting feature of the new laboratories is the panel heating in the floors and ceilings. The panels of hot-water pipes are hidden within the ceilings and give uniform heating throughout the building. The Council Chamber, Lecture Theatre, Canteen and Chemical Laboratories are air conditioned. Electricity, gas, and water are installed in service ducts, chiefly in the corridors and connected by a vertical service shaft.

The Engineering Department

The new laboratories are planned to give ample space for the general chemical and physical research on pottery and refractory materials; the work for the heavy clay industry will continue to be carried out at the Mellor Laboratories at Howard Place. A separate building has been erected at Penkhull for the Engineering Department, and has been equipped with machine tools so that prototypes can be built of new machinery designed by the Engineering Section of the Research Association. A large building to accommodate pilot plant is nearing completion.

The Fuel Department

There is a separate building for the Fuel Department. It has always been an important part of the Association's work to endeavour to reduce the fuel consumption of the industry and to improve the efficiency of firing. The proportion of the heat fed into a kiln as fuel—coal, gas or electricity—that is actually used in the firing of the ware is comparatively small, and if this proportion is to be increased it is important to know how much heat is lost in the flue gases, how much is radiated from the walls of the kiln and how much is lost in other ways. To do this a " heat balance " is made in which all the heat supplied to the kiln is accounted for. The Fuel Department has made such heat balances on many types of intermittent and tunnel kilns and has been able to indicate methods by which the industry's fuel bill can be reduced.

The British Cast Iron Research Association

By Dr. J. G. Pearce, O.B.E.

Director of the Association

An investigation of the subversive influence of certain elements on the production of nodular graphite cast iron is one of the aspects of the work of the British Cast Iron Research Association discussed in this article. Other topics referred to include gases in cast iron, properties of moulding sands, working conditions in foundries, and the analysis of cast iron by means of the direct-reading spectrograph.

DURING the last 12 months there has been a considerable expansion in the laboratory facilities at the Alvechurch headquarters of the British Cast Iron Research Association. When the Association moved from Birmingham to Bordesley Hall in 1942, nearly all the laboratory services were accommodated in the Hall. Since then, numerous buildings have been erected on the adjacent land, and the ultimate goal is to reserve the Hall for the administrative offices and the Intelligence Department and to provide accommodation external to the house for the various laboratories, service departments and melting shop.

The year 1950 saw the completion of a new Machine and Instrument Shop, Sampling Bay and Mechanical Testing Laboratory. Further progress has been made since that date, and on the first of two Open Days held at the beginning of July, 1952, the President, Dr. J. E. Hurst, J.P., formally inaugurated the latest extensions to be completed under the building programme. These include new Chemical and Spectrographic Laboratories, a new Sands Laboratory, accommodation for heavy stores (pig iron, scrap, sands and refractories) and additional accommodation for the Operational Research Team and the Development Department. A Fuels and Furnaces building is now under construction, and a further building is envisaged ultimately to house the metallurgical and chemical research staff.

Direct-Reading Spectrograph

The new Spectrographic Laboratory houses a direct-reading spectrograph of American origin, known as the quantometer. This unit comprises a high precision source unit which can reproduce a considerable variety of electrical discharges, a spectrometer which measures spectra by means of a photo-electric cell system, and a recording cell which records, through an electronic integrating system, the photocell currents produced in the spectrometer. It is anticipated that those elements present in cast iron which are capable of spectrographic determination will be recorded within 60 seconds of the sparking of the sample, and it is hoped also that it may be possible to determine both carbon and phosphorus, elements which are not normally capable of being determined by spectrographic means.

Nodular Graphite Cast Iron

The Association is actively engaged on both long-term and short-term research investigations, and an important aspect of its work continues to be the development of nodular graphite cast iron. Recent work by H. Morrogh[1] has shown the subversive effects of certain elements which are likely to be encountered in British pig irons. He points out that nodular irons produced by the magnesium process, when they are substantially free from subversive elements, will give completely nodular graphite structures, even in heavy sections, and that where instances have occurred of a proportional increase in flake graphite with increase in size of section, the effect may be due to the presence of impurities in the raw materials. Titanium is one of the chief offenders, but small percentages of lead, bismuth and antimony have a pronounced influence, and aluminium in amounts greater than those occurring fortuitously can also have a harmful effect. The reported harmful effect of tin has not been confirmed, and it has been found that tin and arsenic can be present in appreciable amounts without adversely affecting the graphite formation. The harmful effect of copper has not been entirely confirmed, but has been found to be closely related to the subversive element content of the iron. Although this work does not cover all the elements that are likely to affect adversely the production of nodular graphite, it is believed to cover those elements usually found in troublesome quantities in British pig irons. The interesting feature of the investigation is that it has been established that residual contents of cerium of the order of 0·005% in the casting are sufficient to neutralise the effects of these subversive elements. This investigation has led to the development of special analytical techniques for determining chemically the small amounts involved of the interfering elements.[2]

Gases in Cast Iron

Work on the determination of gases by vacuum fusion methods continues, and a high vacuum system, containing a graphite crucible assembly heated by a high frequency generator, is employed for determining oxygen, hydrogen and nitrogen in cast iron in very small amounts, of the ordér of 2 ml. per 20 g.

Some original work has recently been completed on the fluidity of cast iron[3] and work in hand includes the vitreous enamelling of cast iron, chilled and white irons, and shrinkage and porosity in iron castings, these latter problems being studied with the aid of gamma rays.

Properties of Moulding Sands

Work is also in progress on the properties of moulding sands at temperatures corresponding to those encountered during pouring, and the Association has designed and constructed apparatus for evaluating the stress/strain characteristics of sand aggregates both at ordinary and elevated temperatures, and some progress has already been made in relating the results to common casting defects due to sand. The flowability of moulding sands is under investigation, and progress has been made

The direct-reading spectrograph

in studying the influence of synthetic sands in core-making. Synthetic resins are also used in the shell moulding process, which has awakened considerable interest recently in the foundry world, the normal mould being replaced by a thin shell of a resin-bonded silica sand.

Working Conditions in Factories

Two comparatively new departures in recent years have been the establishment of a Foundry Atmospheres Team and an Operational Research Team. The objectives of the Foundry Atmospheres Team are to study means of implementing the recommendations of the Garrett Report[4]. The ironfounding industry has itself made considerable progress in this direction since the war, particularly in providing ablution facilities and similar amenities, but much still remains to be done in improving the general working atmosphere of the foundry. Contributions by the Foundry Atmospheres Team include the improvement of dust extraction arrangements for pedestal type grinders, and by the use of high velocity air streams above and at the side of the working area it has been found possible to keep the breathing zone of the operator clear of dust to a remarkable degree. An investigation has also been carried out on the incidence of carbon monoxide in foundry atmospheres, emanating from both mould driers and the foundry cupola.

The Operational Research Team, which was set up in 1950 to visit foundries by invitation, and subsequently to recommend methods of improving or increasing production, has now made more than 200 visits and has collected a large quantity of valuable data. The number of requests received for a second visit show that the value of this service is fully appreciated.

It is impossible in a brief article to cover all the Association's activities during the last two years. The Association's *Journal of Research and Development* has published about 80 reports dealing with completed research and development investigations, and also papers presented at conferences organised from time to time. The proceedings of a Conference on Heating, Lighting and Ventilation held by the Association in September, 1951, have been separately collected[5] and the considerable demand for this publication shows that the question of improved working conditions in iron-foundries is very much to the fore both among foundrymen in this country and among the manufacturers of equipment.

Conferences held by the Association since the war have dealt with many aspects of foundry work, and the latest, to be held this month, is the ninth since 1948. The emphasis of this latest conference is on the conservation of foundry materials and on processes whose aim is to effect economies in the foundry. Papers will also be included on the simplification of works operations and on rational foundry management.

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South Wales Steel Companies

When nationalisation of the Iron and Steel Industry took place there were cross holdings of shares in three Companies, viz., Richard Thomas and Baldwins Limited, The Steel Company of Wales Limited and Guest Keen Baldwins Iron and Steel Company Limited. The share structure of these Companies has, with the concurrence of the Iron and Steel Corporation of Great Britain, been simplified by transferring to the Corporation from the Companies these cross holdings, so that the Corporation now holds all the shares of these Companies directly.

Following this transfer and by arrangement with the Iron and Steel Corporation of Great Britain, the Boards of the Companies have been reconstituted, and with effect from 3rd October, 1952, are as follows :—

Richard Thomas and Baldwins Limited—E. H. Lever (*Chairman*), H. F. Spencer, L. J. Davies, Sir Robert Barlow, W. F. Cartwright, Capt. H. L. Davies, The Rt. Hon. The Earl of Dudley, Sir Wilfrid Eady, C. G. Gilbertson, S. E. Graeff, Col. A. T. Maxwell, E. J. Pode.

The Steel Company of Wales Limited—E. H. Lever (*Chairman*), Sir Charles Bruce-Gardner (*Deputy Chairman*), E. J. Pode, Capt. H. L. Davies, Sir Robert Barlow, W. F. Cartwright, The Rt. Hon. The Earl of Dudley, Sir Wilfrid Eady, S. E. Graeff, Col. A. T. Maxwell, H. F. Spencer.

Guest Keen Baldwins Iron and Steel Company Limited—J. H. Jolly (*Chairman*), C. R. Wheeler, T. Jolly, J. S. Hollings, Hon. R. G. Lyttelton, K. S. Peacock, N. R. R. Brooke, W. C. Smith.

The foregoing arrangements have been approved by the Minister of Supply.

Bentonite Production in Hungary

Hungarian bentonite resources are now believed to be second in importance only to that country's extensive bauxite deposits. Mining began in the 1930's, and Hungarian bentonite was used in foundry work for the first time in 1941. In 1949 a bentonite research committee was set up with the aim of finding out how best to exploit this product during the five-year economic development plan which began in 1950. As a result of its work, the use of bentonite has spread to 42 different industries, and a surplus for export is now available after home needs are satisfied. A new factory will be opened for the large-scale processing of this commodity.

Open Day at Fulmer Research Institute

Completion of First Five Years' Work on Sponsored Research

Exterior view of the main building.

SOME five hundred visitors, including leading figures in government and industrial circles, attended the Open Day held at the end of last month to mark the completion of the first five years' work at the Fulmer Research Institute. It was founded in 1946 by the late Col. W. C. Devereux, C.B.E., as the first large scale organisation in this country, fully staffed with scientists and equipped with the finest apparatus, to carry out sponsored industrial research, the results arising therefrom, including any patents, belonging solely to the sponsors. This system makes it possible to engage the services of a fully established research organisation to investigate a particular problem for an agreed fee in the same way as one hires the services of a firm of solicitors or accountants.

Colonel Devereux was outstanding among contemporary industrialists in his belief in, and advocacy of, the greater application of scientific research to industrial problems in this country. He was greatly concerned about the tendency, now generally recognised, for so many of this country's most brilliant discoveries in the field of pure science to be ignored until applied overseas to industrial processes and materials. He recognised that the increasing cost of first-class research was making it more and more difficult for industrial concerns, particularly for the small and medium size businesses, to maintain research laboratories on a scale sufficient to do really effective work, and so keep abreast of world developments.

He saw a solution to this problem in sponsored research—a system which had been operated for many years in the U.S.A. and Germany with great success, but which had not hitherto been introduced into this country. It seemed to him that if only one could hire the services of a really first-class research team, complete with all its equipment, a great many more manufacturers would be able to undertake applied research and the general level of our industrial techniques would thereby be improved and made more efficient.

It was in this spirit that the Fulmer Research Institute was founded. It was an enlightened experiment, almost an act of faith, since no one, at the time, could prophesy how such an organisation would fare in this country. However, as will be seen from the following account, the experiment has been a distinct success. "Each of us will use different criteria in measuring success or failure," said Mr. E. A. G. Liddiard, Director of Research, in a speech at the Open Day, "Most of us in the Institute will rightly consider primarily the quality of the work. Others may look at the rate of expansion, and those more directly concerned with the financial side will look at the balance sheet, but whichever way you look at it I think there is cause for satisfaction, although certainly not for complacency."

At the outset it was decided that the Institute should be non-profit-making in the sense that no dividends should be declared to the shareholders, any excess of income over expenditure being ploughed back to provide greater or improved research facilities. On this point, Colonel Devereux remarked on the occasion of the official opening just over five years ago: "I do not make any claim for altruism in this respect. I believe absolutely in the necessity for the rapid application of the latest scientific advances to our manufacturing techniques as a means of keeping up with our competitors all over the world. I also believe that sponsoring research in an independent research institute staffed with the best men available is the ideal way of securing that end."

Since its inauguration, the Institute has doubled its staff, new buildings and equipment have been added and the scale of work has trebled. The total income over the first five years amounted to more than a quarter of a million pounds, 52% of which was from Government Departments, 11½% as direct dollar earnings for research on behalf of Canadian and American sponsors, and 36½% from British industry. It should be emphasised that the Institute is not in receipt of any grants from D.S.I.R. or other government research agencies: such sums as are received from government departments, like those it receives from industrial sponsors, are in payment for work done.

The memorial plaque to the late Colonel W. C. Devereux, C.B.E., which was unveiled on the occasion of the Open Day last month.

Among the sponsors are the Admiralty; various branches of the Ministry of Supply, including the Atomic Energy Research Establishment, the National Gas Turbine Establishment, and the Royal Aircraft Establishment; British Railways; a number of Research Associations; and many leading industrial concerns, including Rolls Royce, Ltd., Chubb & Sons (Lock and Safe) Co., Distiller's Co., Ltd., Morgan Crucible Co., Ltd., Nash-Kelvinator, Ltd., Plessey & Co., Ltd., and the largest aluminium producing companies in Canada and the U.S.A.

Eighty-eight patents have been applied for on behalf of sponsors, of whom there are over a hundred, and twenty-five scientific papers have been published by learned societies.

General Description of the Laboratories

The main laboratories and the library and administration offices occupy a converted Edwardian country house, but the workshops, casting and heat-treatment laboratories, electrolytic laboratories and canteen are located in other buildings added since the Institute was founded. Of the $10\frac{1}{2}$ acres of the grounds, the gardens occupy five acres, part of the remainder has been made into a sports ground, and the rest is reserved for additional buildings of which the next is already planned to house a new mechanical testing, creep and engineering laboratory.

The total floor area available in all the buildings is approximately 22,500 sq. ft., of which some 9,500 sq. ft. are available for experimental laboratories, 1,000 sq. ft. for the workshops, 2,300 sq. ft. for laboratory storage, 2,275 sq. ft. for studies, office and conference room, and 525 sq. ft. for the library, the remainder being taken up by canteen, kitchen, lavatories, corridors, etc.

The Institute has been staffed and equipped primarily to deal with metallurgical problems, but many problems falling within the competence and experience of its staff have already been investigated outside the metallurgical field.

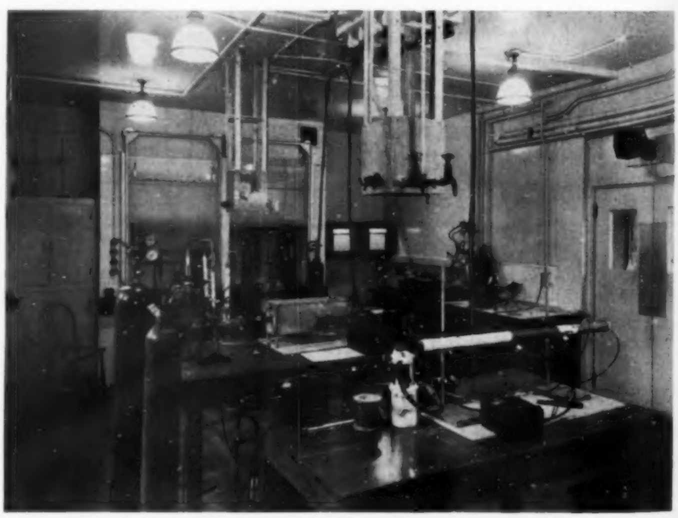
The main departments and their important items of equipment are set out below :—

Chemistry. The vacuum laboratory is equipped for experiments on refining and extraction of metals to be carried out at temperatures up to 1,550° C. in vacua, and for the determination of the kinetics and equilibria of various gas-metal reactions, whilst another laboratory houses an accurate calorimeter designed and constructed for measurements of heats of reaction and heats of formation of metallic compounds. It is proposed to extend the latter facilities to make possible, by determining specific heats at low temperatures, the completion of thermo-dynamic data necessary to calculate equilibrium values in appropriate chemical reactions. Other laboratories are equipped for chemical analysis by "wet," absorptiometric and spectrographic means, and for the study of corrosion and electrodeposition. A separate laboratory has been constructed for electroplating, anodising and electro-polishing.

Physics and Engineering. The physics laboratories are equipped with three X-ray crystallographic sets, 9 and 19 cm. powder cameras, 3 circle Jonesmeter for structural studies, and a high temperature camera capable of operation up to 1,000° C. Single and double monochromators, using bent quartz crystals, are in use to study precipitation phenomena by techniques developed in collaboration with Professor Guinier. Apparatus is also available for dilometric work and for the determination of thermal and electrical conductivities.

Tensile, fatigue (Haigh and Wöhler), bend and impact tests are carried out at room and elevated temperatures, and the mechanical testing equipment includes Vickers, Brinell and Rockwell hardness testing machines. High temperature hardness tests can be made on an adapted Rockwell machine. For strain gauge measurements on structures, a fifty-channel bridge is available.

Five precision tensile creep testing machines are available for operation at temperatures up to 1,000° C., whilst four compressing creep testing units can be used for rapid sorting of creep resisting alloys and for comparing creep in tension and compression. Apparatus

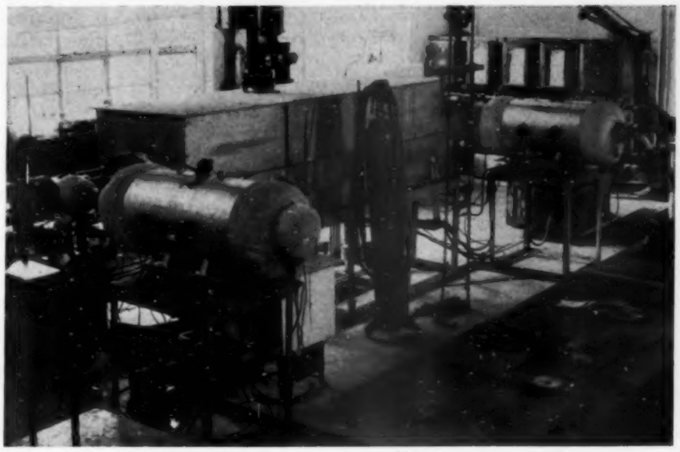


The new physical chemistry laboratory.

has also been built for measuring the damping capacity of wires while they undergo creep under tensile stress at elevated temperatures.

Metallurgy. For metallographic work a Bausch and Lomb research metallograph is supplemented by four bench microscopes. Micro-hardness tests can be carried out, and apparatus is also available for thermal analysis and for the measurement of instantaneous heat applied to the study of alloy constitution.

In addition to indirect arc, resistance, and oil-fired melting furnaces, a 20 kVA high-frequency induction furnace with coils for open, or for vacuum or special atmosphere melting and casting is in use. On the metal working side, an 80-ton press is available for hot or cold pressing of metals and alloys, or for powder metallurgical work. Together with a 1-cwt. forging hammer due for delivery this month, the press will be installed in extensions to the present experimental foundry.



The pilot plant for the catalytic distillation of aluminium.

There is also equipment for sieving, sand testing, sand blasting, metal and paint spraying, and core drying, together with the techniques necessary for making precision castings by the " lost-wax " process.

Miscellaneous. Other sections include laboratories for research on ceramics and heat treatment and there are semi-technical laboratories for the erection of experimental plant. At present the latter are occupied by plant for catalytic vacuum distillation which is capable of producing up to 2 lb. of aluminium of exceptionally high purity per hour.

The workshops, where much of the Institute's apparatus has been made, are equipped with a complete range of machine tools, including a universal miller and grinder and three precision lathes.

The library contains about a thousand text and reference books and volumes of translations and abstracts of scientific societies: reprints of articles of special interest are also catalogued. Contacts have been made with outside libraries and information and advice based on published work can be given quickly on a wide variety of subjects.

A Selection of Results Achieved

Many of the researches undertaken by the Institute cannot be described in detail since the results are confidential to the sponsors. It can be said, however, that they cover a wide field, ranging from investigations on such everyday things as boxes for the transport of fish, television aerials, fire-extinguishers, safes, dentists' forceps, industrial diamonds, pen-nibs, salt and furniture to more obstruse studies of such phenomena as oxyethylation of wool wax alcohols, hydrogen embrittlement of steels, properties of metal-ceramic aggregates, creep of metals, and heats of formation of metal halides.

Among the many successful developments arising from the researches carried out at Fulmer, are the development of a new high-strength aluminium alloy, Aluminal 500; an entirely new method of producing and refining aluminium of high purity; a new series of bearing alloys; and ceramic coatings for lining the combustion chambers of gas turbine engines.

Other important researches in progress include the development of new methods of producing titanium, beryllium and other metals and metal-ceramics, not so far produced on a commercial scale, but now urgently needed to play their part in new engineering developments such as supersonic flight, atomic energy production and gas turbine engines.

As an indication of the success which has attended the Institute's activities, a few of the results may be considered in rather more detail.

Catalytic Distillation of Aluminium.—From a consideration of spectroscopic data and observations on the distillation and subsequent condensation of aluminium in the presence of cryolite, Dr. Gross, Fulmer's principal scientist, deduced that aluminium must form monovalent halides at high temperature and low pressure, and that the reversible reaction $2Al + AlX_3 \rightleftharpoons 3AlX$ (where X is a halogen) could be used to distil aluminium by bringing the vapour of the trivalent halide in contact with the aluminium-bearing material at high temperature and low pressure, and then cooling the resulting vapour of aluminium monohalide to condense the aluminium and re-form the vapour of the original trivalent halide.

To be commercially feasible, it is necessary for the aluminium and the halide to condense at widely differing temperatures. If aluminium chloride is used, this condition is met, and Dr. Gross went on to prove experimentally that high purity aluminium can be obtained by the reaction between aluminium chloride and impure aluminium. The process may be used for purifying scrap or aluminium of commercial purity, or for the extraction of aluminium from alloys produced by direct thermal reduction in the arc furnace. Further laboratory work is in progress under the joint sponsorship of Aluminium Laboratories, Ltd., and International Alloys, Ltd., and on the small scale experimental plant illustrated.

Indirect Distillation of Metals.—By another method, i.e., that of intermediate formation of its stable halide, beryllium has been distilled at temperatures far below those at which its vapour pressure is sufficiently high for its direct distillation. The method is applicable to a wide range of other metals.

High-Strength Aluminium Alloys.—The " 500 " series of aluminium alloys is the outcome of a fundamental

Application of the new "500" series of aluminium-copper-cadmium alloys in the form of forgings, extrusions and sheet.

investigation of the mechanism of precipitation hardening in alloys, in which it was observed that very small quantities of third elements could affect the amount and rate of precipitation hardening in aluminium copper alloys. Small quantities of cadmium added to aluminium—5% copper alloy delay room temperature hardening after solution treatment, but accelerate and increase the amount of hardening which takes place at slightly elevated temperatures. The aluminium-copper-cadmium alloy in the fully heat treated condition has properties at least equal to those of the normal duralumin type, but shows a remarkable facility for hot working by forging or extrusion, and does not age at room temperatures after solution treatment. The alloy may, therefore, be fabricated more cheaply and at a greater rate than the conventional duralumin-type. It is not necessary to carry out cold working operations such as bending and dressing immediately after solution treatment, or to refrigerate the alloy, as is necessary in the case of duralumin-type alloys, to avoid room temperature hardening. Development work is proceeding with various firms in the industry in collaboration with the Ministry of Supply, who sponsored the original research work. In the solution treated condition, the alloy has a 0·1% proof stress of 7 tons/sq. in., a U.T.S. of 18 tons/sq. in., and an elongation of 35%, the corresponding figures after full heat treatment being 27 tons/sq. in., 32 tons/sq in. and 10%.

Aluminium-Tin Bearing Metals.—Research under the sponsorship of the Tin Research Institute has led to the development of new aluminium-tin bearing metals containing about 30% of tin. The alloys investigated cover a wide range of strength and hardness with the aim of suiting particular conditions of service.

Although aluminium-tin alloys containing less than 10% of tin have been used in the past and it was known that the anti-friction properties of alloys of this type improved with increase in tin content, alloys containing more than 10% of tin were found to be mechanically weak. It has now been shown that by a process of cold working followed by recrystallisation heat treatment, the tin, instead of being at the grain boundaries, can be redistributed in a dispersed form, with great improvement in mechanical properties, particularly at the slightly elevated temperature at which bearings operate.

Bearing tests by the Tin Research Institute have shown that the alloys containing 30% of tin have a high fatigue resistance and promising results are reported on engine trials with the new material. Considerable interest has been shown in these alloys in the U.S.A. where they were the subject of a paper given to the World Metallurgical Congress, held in Detroit in October, 1951.

Ceramic Coatings.—The problem of distortion and cracking in combustion chambers of gas turbines is one of the most serious limitations of the life of such engines. Heat reaches the wall of the combustion chamber partly by convection and partly by direct radiation from the hot flame. The heating by radiation can be minimised by the application of a low emissivity coating, i.e., one which will reflect rather than absorb the radiated heat. The effects of over-heating can also be minimised by protecting the metal of the combustion chamber, or flame tube, from oxidation: the two problems are quite distinct.

Success in the development of a low emissivity coating was attained by first measuring the emissivity of various refractories of different particle size, and then developing bonds suitable for sticking selected low emissivity refractories on to the appropriate metal. Service trials are in progress on suitable coatings, and patent protection has been applied for. Work is continuing on coatings to suppress oxidation. This work is under the sponsorship of the National Gas Turbine Establishment.

Corrosion of Light Alloys.—With the object of obtaining data on the probable life of light alloy structures in various conditions of atmospheric exposure, samples in both the stressed and unstressed condition have been exposed at a number of sites. The results confirm that normally the rate of corrosion of aluminium-base alloys in the atmosphere tends to decrease with time and, provided the original thickness is adequate, an almost infinite life can be predicted. Certain conditions of exposure, particularly those involving heavy condensation in a relatively still atmosphere, and the accumulation of corrosion products or certain types of deposit, cause very rapid attack.

The course of corrosion in certain types of extruded specimens is unusual. Attack tends to occur preferentially along lines parallel to the original section of the extrusions, causing corrosion to occur in layers, with the formation of blisters. In certain conditions, stress corrosion and intercrystalline corrosion in alloys otherwise subject to this form of attack is completely absent but the direction of stressing relative to the direction of extrusion is of major importance.

This work has been sponsored jointly by Almin, Ltd., and the Ministry of Supply.

Conclusion

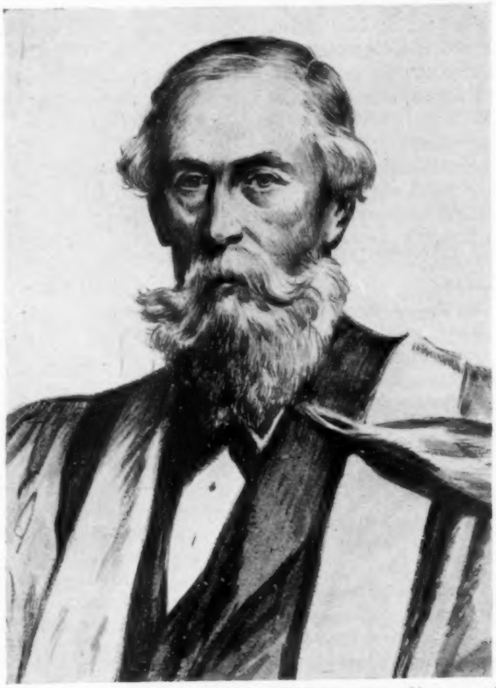
During the past five years, the amount of work sponsored by British industry has shown a steady increase, and its value stands at present at about £10,000 per annum, but it remains true to say that the value of sponsored research is more fully recognised on the other side of the Atlantic than it is here, and that it is easier there to sell the idea that research pays dividends. It is the hope of the Institute that in another five years it will be possible to present a picture in which its service to British industry is very much to the forefront.

Henry Clifton Sorby

A Pioneer in Metallurgical Microscopy

By Eric N. Simons

In his efforts to apply the microscope to the study of geological and metallic specimens, Sorby met with a good deal of scepticism, if not open ridicule, but his perseverence was rewarded in both cases, and to-day he is regarded as being responsible for the introduction and early development of metallurgical microscopy, which remains one of the most important means of investigation at the disposal of the metallurgist.



IT is not always the greatest of pioneers who attain fame, and conversely, in many instances men of outstanding importance fail to achieve the reputation they deserve. Henry Clifton Sorby is far less well-known to the world than Bessemer or Siemens, yet his is unquestionably one of the greatest names in the history of metallurgical science. Born in Sheffield, at Woodbourne, on May 10th, 1826, Sorby was a member of one of the oldest families of that great city. One of his ancestors, Robert Sorsby, as the name was originally spelt, was the first Master Cutler in 1624, and nearly 200 years later—in 1806, to be precise—his grandfather, John Sorby, became Master Cutler also. There are still members of the Sorby family manufacturing steel in present-day Sheffield, so that it can be said of Henry Clifton Sorby that he was a strong link in a long chain of Yorkshire steel manufacturers.

Henry Sorby, the father of Henry Clifton, married Amelia Lambert, of London, a lady of great intelligence and charm, and the subject of this article was the product of their union. Henry Sorby senior, a member of the firm of John and Henry Sorby, makers of edge tools, sent his son to be educated at the Collegiate School, Sheffield, now known as King Edward VII School for Boys. Young Sorby was brought up in affluence, and there was no severe economic pressure upon him to take up a profession. In consequence, he was able to follow his own bent, which took him in the direction of mathematics, natural science and water-colour painting, under a tutor at his own home after his schooldays were over.

It will be seen that there was, for a time, a conflict in him between art and science but in the end, science won, and Sorby devoted the remainder of his life to research. This research was by no means confined to metallurgy, but embraced geology, archeology, chemistry, botany and Egyptology. His first research was into animal and vegetable chemistry, and papers written by him on these themes appeared in 1847. His home was at Woodbourne Hall, situated between Woodburn Road and Ripon Street in that region of Sheffield where Attercliffe and the Park district meet, not far from the Don river. The Rother at its widest point passed through his father's estate at Orgreave, and in this latter river were to be found considerable alluvial deposits, on which he worked, drawing maps to indicate the manner in which each stream had diverged from its original bed.

Geological Microscopy

In 1849, he made the, at the time, astonishing suggestion that the microscope might very well be employed in geology, but the idea was greatly ridiculed, and someone termed it "examining a mountain with the microscope." Sorby, who had been spending much time studying the Isle of Wight and the Dorsetshire coast, as part of an investigation into current structures, was in no way convinced by the arguments brought against him. He actually used the microscope as a means of studying calcareous grit discovered on the Castle Rock at Scarborough. This novel use of the instrument he ventured to describe in a paper read in 1850 to the Geological Society, and as a result, much of the initial opposition to the idea disappeared. In 1851 he paid some attention to slaty cleavage and, as a result, proved that some of the original theories could no longer be entertained. Many of these had actually been put forward by the experts of the Geological Survey.

His undying interest in natural products caused him next to study limestone, and his invention of the polarising microscope was of great importance in the following up of inquiries into the distribution of animals, based on the valuable collections he had made from the oceans and estuaries during his voyages in his yacht *The Glimpse*. In 1850 he was elected a Fellow of the Geological Society of London, and 19 years later he received the Wollaston Medal, becoming President of the Society in 1878 and retaining that office during 1879. He was elected a Fellow of the Royal Society in

1857, and in 1863 gave the Bakerian Lecture. In 1874 he was awarded a Royal Medal for his inquiries into minerals, rocks, etc., and in 1879, the University of Cambridge conferred upon him the honorary degree of D.Ll. From the Dutch Society of Science, of Haarlem, he received the first large Boerhave gold medal, which is awarded only once in 20 years. In 1877, he became President of the Mineralogical Society of Great Britain and Ireland.

Many minor honours fell to him during a most fruitful period, but these, coming from many countries, it would require too much space to enumerate. He was a member of the Commission on the Drainage of London in 1882, and spent the best part of a year on his yacht, studying the silting up and erosion of the estuaries, as a result of which he was able to produce an extensive budget of facts of inestimable value to the Commissioners.

Despite the wide area he covered geographically in the course of his researches, he never abandoned his native city of Sheffield, and in 1883 became the originator, or one of them, of the first technical school ever to be opened there, being its first Chairman and a most generous patron. He also presided over the School of Art and Mechanics Institute.

When he turned his attention to iron and steel, he inevitably brought to bear upon these metals and their structure the microscope which had already demonstrated its worth in relation to geological research. When, in a paper given at Bath to the British Association, Sorby stressed the benefits to be obtained from the microscopical study of the structures of iron and steel, Sheffield metallurgists laughed at the notion, but 23 years later the Iron and Steel Institute itself invited him to read a paper on that very subject. This innovation has always been considered one of the major developments in practical metallurgy.

Sorby is one of the few men who have had the honour of giving their name to a structural constituent of steel: the term "sorbite" forever commemorates him. He lived for the greater part of his life with his widowed mother in Sheffield, and it was after she died in 1872 that he purchased his yacht *The Glimpse*, but he took care to spend every winter in the city of steel. The yacht was of 35 tons, with a captain and a crew of four, and Sorby himself rowed many hundreds of miles in a small boat attached to the yacht, using the bigger vessel for the longer expeditions.

A skilled water-colour painter, Sorby died on March 9th, 1908, at his home at Beech Hill Road, Sheffield, having attained the age of 81. His great contribution to metallurgy was, as stated, the discovery that "different kinds of iron and steel were varying mixtures of well-defined substances, the structure of which had much in common with that of igneous rock." He may be regarded as the pioneer of microscopic metallurgy.

Metallurgical Microscopy

In his own words, Sorby considered it natural that he should be led from the microscopical study of the structure of rocks to that of meteorites, and to explain the structure of meteoric iron, he began the study of artificial irons in 1863, giving an account of it to the British Association in 1864. This attracted no attention for 22 years, but in 1887, the Iron and Steel Institute asked him to take up the matter again, appointing Dr. Percy, Sir Henry Bessemer and himself to decide the best way of illustrating a complete paper on the subject. This was done, and after that the microscopical investigation of iron and steel was recognised as an important means of studying these metals.

In those early days, if a railway accident had occurred, and he had suggested that the company should take up a rail and have it examined with the microscope, he would have been looked upon as a fit man to send to an asylum. What he really proved, Sorby said, was that various types of iron and steel were mixtures, as outlined above. He also took specimens of iron and steel and acted upon them with acid, so that it was possible to print from them as from types, and show many interesting points connected with their structure.

Sorby was thus the first to employ what is known to-day as macro-etching as a means of studying the crystal arrangement and grainflow of castings and forgings. This is the "printing" to which he refers in the remarks made at the end of the preceding paragraph. From his earliest observations, he was extremely interested in the constituent of iron and steel to which he gave the term "Pearly" (it is known to-day as "pearlite"). He rightly declared it to be a mixture of two components. Though he discovered this in 1864, it was not until 1885 that by means of what was then an exceptionally high power of magnification (650) he was for the first time able to separate the two components and recognise them as "free iron" and "hard iron." In a paper dated 1887, on the microscopical structure of iron and steel, he gave the general character of the chief constituents he had detected as:—

(i) free iron as in malleable (*i.e.*, wrought) iron;
(ii) carbon in graphitic form in cast iron;
(iii) the pearly constituent containing a mixture of free iron and iron carbide;
(iv) iron combined with carbon, as in white iron;
(v) small ruby and dark crystals, possibly silicon;
(vi) the residual compound in cast iron.

He was not sure of the identity of the dark crystals, but these were later shown by another worker to be red "cyanonitride" and the blue titanium nitride. The character of the residual compound of cast iron was also at that time in doubt, but was probably a phosphide eutectic, which was also identified at a later date by the same worker.

In a paper delivered in 1886, Sorby suggested an explanation of the hardening of steel that may be regarded as the germ of the modern theory of solid solutions. His actual words were:—

"What I have been able to see with high powers shows that when strongly heated the constituents combine, and when suddenly chilled, there is no evidence that they separate, although it is possible that this may be because the particles are too small to be separately defined. It, however, seems to be very probable that in the hardening process the unstable compound may not break up into soft iron and the very hard brittle constituent, but may be suddenly fixed so as to give great hardness combined with strength. According to this view, the peculiar properties of Mushet's self-hardening steel may be due to the presence of tungsten preventing this usual separation. That the softening of hardened steel depends on a separation of the two constituents seems proved by what is easily seen when the heat has been maintained for a considerable time."

NEWS AND ANNOUNCEMENTS

Institution of Mining and Metallurgy

Election of President

The Council of the Institution of Mining and Metallurgy have announced the election of Professor J. A. S. Ritson, O.B.E., D.S.O., M.C., as President for the Session 1953–54. He will take office at the General Meeting to be held on May 28th next.

Professor Ritson was educated at Uppingham School from 1902–06. He then entered the University of Durham where he obtained a B.Sc. degree in Mining in 1910. After obtaining his Colliery Managers' Certificate he acted for a time as manager of a colliery in Northumberland and then became an Inspector of Mines. At the outbreak of the 1914–18 war he was mobilised with his Territorial Battalion, the 8th Durham Light Infantry, and served in France with the 50th Division from April, 1915, until he was severely wounded. Later he commanded the 12th Battalion of the Royal Scots in the 9th Division. He was awarded the Distinguished Service Order and Bar, the Military Cross and the Order of the British Empire.

In 1923 he was appointed to the Chair of Mining at the University of Leeds where he remained until invited to the Royal School of Mines in 1935. During the recent war he was Director of Supplies at the Ministry of Fuel and Power until the middle of 1942. He has served on many Government and Departmental Committees, including the Committee on the Mineral Resources of Great Britain, and the Board for Mining Examinations. Professor Ritson, who is a Past President of the Institution of Mining Engineers, was elected a Member of the Institution of Mining and Metallurgy in 1936, and has served continuously on the Council since 1940, for three sessions as Vice-President.

United Steels' Short Course for Undergraduates

At the invitation of The United Steel Companies, Ltd., 36 students of pure science, engineering and metallurgy, from the universities of London, Sheffield, Leeds, Southampton, Cambridge, Bristol and Birmingham, spent a week in Sheffield as guests of the Company from September 22nd to September 27th, 1952.

The aim of the course was to give an insight into the scientific foundation of iron and steelmaking and of certain derivative chemical manufacturing processes, and the scope of engineering and research in the industry. Some idea, too, has been given of the economic structure of the industry. An indication was, therefore, given to the undergraduates of the opportunities available within the steel industry and it is hoped that it will benefit those who attended and will assist them in deciding the sort of career they would like to follow after graduating.

The undergraduates were in residence at University Hall, Sheffield, under the supervision of Mr. T. Fletcher, T.D., Company Training Supervisor, who was in residence with them during the course.

The guests arrived in time for dinner on Monday, September 22nd, and were welcomed by Mr. F. H. Saniter, Director of Research and by Mr. D. R. O. Thomas, Chief Education Officer. During their week's visit they studied the work of a fully integrated iron and steel plant at Appleby-Frodingham Steel Company, Scunthorpe (Tuesday); visited the Company's new Research and Development Department at Swinden Laboratories, Rotherham on Wednesday; observed the manufacture of alloy steels and finishing processes such as fine wire, stainless steel and cold rolled precision strip at Samuel Fox & Co., Ltd., Stocksbridge (Thursday), and visited the works of Steel, Peech & Tozer, Rotherham, and The United Coke & Chemicals Co., Ltd., Treeton (Friday).

The undergraduates were entertained to dinner each evening at University Hall where they met representatives of the Board, Management and Head Office staff and had the opportunity of discussing points of detail with them. After dinner the day closed with a talk on some aspect of the steel industry, or a brains trust or a general discussion.

Symposium on Caustic Cracking in Steam Boilers

A Symposium on Caustic Cracking in Steam Boilers will be held under the auspices of the Corrosion Group of the Society of Chemical Industry at The Institution of Mechanical Engineers, Storey's Gate, St. James' Park, London, S.W.1, on Thursday, 20th November, 1952. The morning session will extend from 9-45 a.m. to 12-30 p.m. and the meeting will be continued from 2 p.m. to 5 p.m. Papers will be presented in person by Dr. A. A. Berk (U.S.A., Bureau of Mines), Mr. P. Hamer (Imperial Chemical Industries Ltd.), Dr. J. Lodder (MEKOG, Holland), Dr. R. N. Parkins (University of Durham), M. R. Rath (Electricité de France), Mr. R. Ll. Rees (British Electrical Authority) and Dr. C. D. Weir (Messrs. Merz and McLellan).

It is hoped that this Symposium, with contributions by leading authorities from home and abroad, will provide the occasion for taking stock of the present position of the problem, thus permitting clarification that is much needed concerning the relative incidence of caustic cracking under various conditions of service and the measures most appropriate for its prevention.

"Foundry Practice" Short Article Competition

Awards in connection with the above competition have now been made as follows :—

1st prize of £15 to Mr. F. J. McCulloch, Lightcliffe, Nr. Halifax.

2nd prize of £10 to Mr. F. J. Timbrell, Stanningley, Leeds.

3rd prize of £7 10s. to J.A.L.

4th prize of £5 to Mr. D. F. Roper, Dudley, Worcs.

Six consolation prizes of book tokens value 30s. and several special awards of wallets were also made. A total entry of almost 60 articles was received, and in the opinion of the panel of judges: Mr. J. Bamford, Head of the National Foundry College; Mr. L. G. Beresford, Editor *Metal Industry*; and Mr. E. J. Groom, Editor, *Light Metals*, a very high standard was reached. Winning entries will be published in forthcoming issues of *Foundry Practice*.

U.S. Approval for Nu-Swift

NEGOTIATIONS over the last five years have resulted in the acceptance and approval in the United States of a pressure-operated fire extinguisher manufactured by Nu-Swift Ltd. This is the first foreign-made fire extinguisher ever approved for use in the United States. The approval of this extinguisher on behalf of the Associated Factory Mutual Fire Insurance Companies opens up a considerable dollar export field for Nu-Swift pressure-operated extinguishers.

New High Temperature Resistance Alloy

AFTER several years of intensive research, a new "Superheat" type of electrical resistance material for use in air has been developed by AB Kanthal, of Hallstahammar, Swedish pioneers in the production of electrical resistance materials. Capable of withstanding temperatures of 1,600–1,700° C., the alloy is expected to exert considerable influence on the design of high temperature furnaces.

The new material, which is a powder-metallurgical product based on molybdenum, is expected to be on the market towards the end of the year. In developing the product at the Kanthal laboratories, the manufacturers have had in mind in the first place its utilisation for dental furnaces, laboratory equipment and for firing ceramic products. It is expected, however, that the alloy will also be suitable for other purposes.

Churchill Gold Medal

PRESENTATION of the Churchill Gold Medal of the Society of Engineers to Air Commodore Sir Frank Whittle, K.B.E., C.B., F.R.S., Hon.F.S.E. was made at the Apartments of the Geological Society, Burlington House, on October 6th, 1952. The award which had been approved by Mr. Winston Churchill, who is an Honorary Fellow of the Society of Engineers, is made for the most noteworthy development in engineering or contribution to contemporary engineering. It is the first award to be made by this Society.

More Iron Ore Wagons

DURING the first eight months of this year British Railways carried approximately 10 million tons of iron ore, an increase of more than 900,000 tons compared with the same period in 1951. In 1953, iron ore carryings by rail are expected to amount to over 17 million tons, an increase of 2,800,000 tons above those in 1951. To provide for this increase British Railways are to build in their own workshops, at Shildon, Co. Durham, 1,240 more ironstone tippler wagons of 27 tons capacity to supplement the present stock of 2,300 wagons of this type and the existing fleet of hopper wagons.

A New Profit-Sharing Scheme

WOLF ELECTRIC TOOLS, LTD., have recently introduced a novel profit-sharing bonus. Original in its concept, the scheme is devised to underline the community of interest between capital, labour and management, and to promote the sense of partnership between them. Manual workers and clerical staff can all become eligible to participate in the bonus which takes the form of a "dividend," and individual shares are varied with normal time-work earnings and years of service with the company.

Personal News

MR. R. A. HACKING, O.B.E., has been appointed Director of Research of R.T.S.C. Laboratories, Aylesbury, which is a joint research organisation of Richard Thomas & Baldwin's and The Steel Company of Wales.

MR. F. C. GOLDSMITH, has joined Foundry Services Ltd. to become their resident technical representative in India and Pakistan. Mr. Goldsmith was previously on the home sales staff of Morgan Crucible Co. of Battersea, London.

MR. C. E. PROSSER has been appointed Deputy Chairman of the Metals Division of Imperial Chemical Industries, Ltd. Mr. Prosser will be succeeded as Joint Managing Director, Metals Division, by MR. M. J. S. CLAPHAM, who is at present I.C.I. Midland Regional Manager and a member of the Metals Division Board.

MR. WILLIAM MURE, C.B.E., Director of Amalgamated Metal Corporation, Ltd., has been elected Chairman of the Council of the Zinc Development Association in succession to MR. S. C. HUNN, a Director of Enfield Rolling Mills, Ltd.

MR. J. CARTWRIGHT sailed last month for Stockholm to take up his duties as resident technical representative of Foundry Services Limited in the Scandinavian countries. He will work in close co-operation with the company's established agents.

MR. A. SMART has been appointed a Director of Electric Furnace Co., Ltd.

MR. H. F. SPENCER, Assistant Managing Director of Richard Thomas & Baldwins, Ltd., has been appointed a Managing Director.

MR. H. C. WILSON BENNETTS has been appointed Director of Sales to Allied Ironfounders, Ltd., in place of MR. W. T. WREN, who has now become Assistant Managing Director.

MR. T. DENNISON has left B.I.S.R.A. to join the technical staff of the British Iron and Steel Federation.

MR. F. HAUGHTON, Director of Pickford, Holland & Co., Ltd., has been elected President of the Refractories Association of Great Britain for the year 1952–53.

Obituary

WE regret to record the death of Mr. Duncan MacArthur, Director and General Sales Manager of Metropolitan-Vickers Electrical Co. Ltd., who died suddenly at his home in London on October 7th, 1952. Mr. MacArthur had spent the whole of his business life with Metropolitan-Vickers, having joined the Company (then British Westinghouse) in September, 1906. The early part of his career was spent in Glasgow, and in 1919 he became Manager of the District Office there. In 1935 he was transferred to London, being appointed Manager of the London Office. In 1943, Mr. MacArthur was elected a Director of the Company, and in the following year he became Manager Home Sales. In 1945 he was appointed General Sales Manager. He also joined the Board of the M-V Export Company. Mr. MacArthur was Chairman of Newton Victor Ltd. and Newton and Co. Ltd., and a Director of Metropolitan-Vickers South Africa (Pty.) Ltd., Metropolitan-Vickers-GRS Ltd. and Sunvic Controls Ltd.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

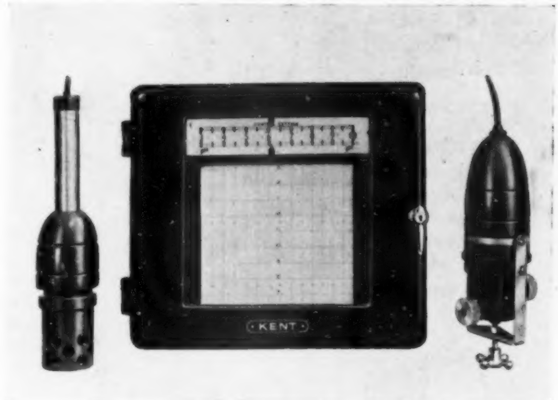
Continuous *p*H Recorder/Controller for Industry

A NEW Universal glass-electrode *p*H recorder, which now makes possible the automatic control of many industrial processes is introduced by George Kent Ltd. Continuous measurement of the *p*H value of industrial solutions, due to inherent difficulties, has been associated with unreliability and complicated and frequent maintenance. It is claimed for the Kent instrument that maintenance has been reduced to reasonable proportions, and that it will provide accurate and continuous records of *p*H over periods of several months without any maintenance attention whatever, the addition of potassium chloride to the salt bridge being also unnecessary. Furthermore, it is claimed that the new instrument does not have its accuracy affected by sampling under pressures up to 75 lb./sq. in. Plug-in electrodes with quick-acting glands represent the third unique feature of the Universal recorder, of particular value where the sampling conditions are such as to cause rapid fouling of the electrodes, and making cleaning a simple matter.

The primary element, the body of which is made of high-temperature grade material, can be used in two ways. The *tank-type* can be arranged so that the electrodes just dip into the liquid to be measured, or the electrode system can be completely submerged. This type has a built-in support complete with a quick-acting clamp. By simple replacement of accessories, the tank-type is converted into the *flow-type*, in which the liquid to be measured flows through a sealed hopper fitted on to the electrode holder. This type may be used for measurement under pressure. Both types are robust and streamlined, all parts in contact with the sample being made from non-metallic materials highly resistant to the vast majority of attacking agents.

The combined reference/salt bridge electrode is unbreakable and pressure compensated. The liquid junction is resistant to fouling and is a separate component which can be replaced quickly at negligible cost. The three types of glass electrode (general purpose, high temperature and high *p*H) cover virtually the full theoretical range of the *p*H scale. A nickel resistance thermometer, protected by a moulded rubber sheath, provides automatic temperature compensation for the electrodes.

The measuring system is in two parts—an electrometer and a recorder. The special impulse-type electrometer, operated from the A.C. mains, measures the potential of the electrode system without imposing any significant load on the system. The electrometer circuit has an extremely high input impedance which is symmetrical with respect to earth, making possible the use of robust and service-free electrodes. Only one valve is used in the electrometer and replacement is both cheap and easy as a standard radio type has been chosen. Variations in the valve characteristics do not cause zero drift, and changes in mains supply voltage do not affect the accuracy of the instrument. The electrometer is housed



in a strong sealed case which can be mounted up to 100 feet away from the primary element. The self-balancing potentiometer/recorder may be located up to 500 feet from the electrometer.

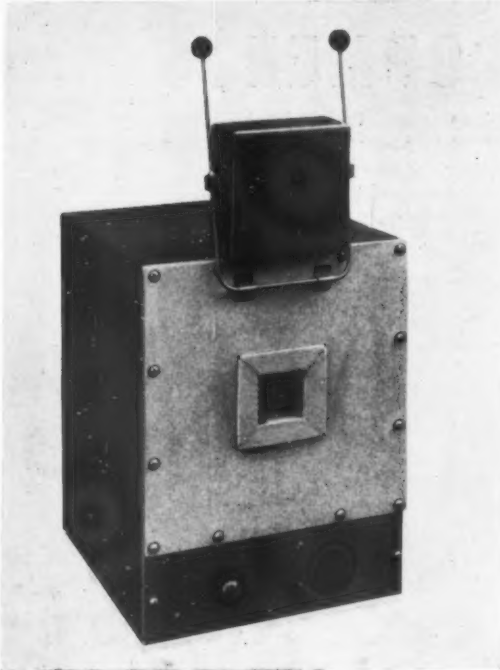
One most important effect of the new instrument should be stressed. Automatic control can now be applied for the first time to a number of industrial processes. Processes involving the circulation of hot process liquor, for example, can be automatically controlled pneumatically with the aid of the new Universal recorder. Until now the time-lag involved in cooling a sample has ruled out automatic control with previous *p*H instruments.

Electric Muffle Furnaces

ONE of the interesting features of the new range of small electrically heated muffle furnaces being put on the market by Gradec Ltd. is the novel balanced rising door fitted to them. The advantage of a rising door is that the operator is not presented with two hot surfaces when the door is opened, and in this case the vertical movement is achieved by means of an ingenious lever system in place of pulleys and counterweights. The door handles being well away from the furnace are kept cool and there is no danger of burns to the operator.

There are three standard muffle sizes, $2\frac{3}{4}$ in. high × $2\frac{3}{4}$ in. wide × 8 in. deep; $4\frac{1}{2}$ in. high × 7 in. wide × 14 in. deep; and 7 in. high × 7 in. wide × 11 in. deep, but other sizes to customer's specifications can be accommodated in the same shells. The muffle is made of high-grade moulded refractory material and is wound with Kanthal A wire. It is solidly supported by means of high-quality insulating breaks and powder, the bricks being chosen so as to work at 200° C. below the maximum recommended temperature. The door is built of sheet steel and insulated by a special BVC concrete, which gives longer life than bricks. The furnace has a pleasing durable silver-hammered enamel finish.

Each size of furnace is available for operation up to either 1,000° C. or 1,200° C., and the rating and insulation



of the furnace are such as it gives the shortest practicable heating-up time and the power required to maintain the top temperature is only a small fraction of the rating. The standard control equipment consists of a heavy contactor, energy regulator, indicating lights and all the necessary fuses. The control gear is housed in a drawer at the bottom of the furnace, held in place by two or four screws, thus providing for easy access for checking and maintenance purposes. If required a pyrometer can be mounted on the side of the furnace and provision made for fitting a thermocouple, thereby making the whole unit self-contained.

Gradec Ltd., 96, Hackney Road, London, E.2.

Rust Remover

THE latest preparation of Croda, Ltd., Metacon 516, is an improved rust remover of the phosphoric acid type but contains certain specific additives which are claimed to give it special desirable properties.

Metacon 516 leaves ferrous metal surfaces with a matt finish devoid of undesirable excessive crystalline appearance, which is an advantage where paint has to be applied later. Such surfaces do not need neutralising after dipping, nor will they re-rust for some time after the Metacon 516 has dried. Under industrial chemical laboratory atmospheric conditions, Metacon-treated mild-steel panels remained free from corrosion for at least eight weeks continuous exposure. In using Metacon 516, the metal surface being de-rusted is not attacked to a greater extent than that the surface loses less than 0·039 oz./sq. yd./hour, whereas, 25% phosphoric acid solution, a commonly used rust remover, will give a loss of 0·2 oz./sq. yd./hour of contact.

For satisfactory results, it is essential that efficient degreasing precedes the Metacon treatment, and owing to its drastic action on aluminium and its alloys, even in the cold state, care is necessary in treating composite articles which may contain these particular metals.

Metacon is supplied in two grades, 516 (concentrated) and 520 (diluted), and no special plant is needed beyond a lead-lined, stoneware, enamelled or stainless steel tank to hold the fluid. The tank should be capable of being heated as, for many purposes, an operating temperature of 50°–60° C. is recommended.

Croda, Ltd., Croda House, Snaith, Goole, Yorks.

Multi-Roll Leveller

A RECENT development of the Bronx Engineering Co., Ltd., is a 13-roll levelling machine with double rows of support rolls capable of levelling sheets and light plate up to $\frac{5}{32}$ in. thick, in widths of up to 8 ft., which is unusually wide for this type of machine.

The main housings are of cored semi-steel castings of tie bar construction with massive upper and lower beams on which the support roll bearings are mounted. In this way all stresses are self-contained by the tie bars, deflection being negligible. The height of the upper set of rolls can be controlled by a large hand wheel, two smaller hand wheels giving individual adjustment to the ingoing and outgoing rolls.

The machine is arranged for levelling in forward and reverse running positions, which means that for setting and other purposes the sheet can be reversed while in the machine for levelling in either direction. For this purpose both ingoing and outgoing top levelling rolls have independent adjustments, and are not supported, and therefore of larger diameter than the supported levelling rolls.

A graduated scale indicator is fitted showing the position of the top roll bank and separate indicators giving the position of each ingoing and outgoing top roll.

The Bronx Engineering Co., Ltd., Dudley Road, Lye, Stourbridge, Worcs.

Gas Welding Rods

THE range of oxy-acetylene welding rods made by the Suffolk Iron Foundry (1920) Ltd., has been increased by the addition of two new rods—the Sifonite No. 18 hard surfacing rod, and a special new bronze rod containing 22% nickel. The former is a special cast hard alloy developed to eliminate wear caused by heat, corrosion and abrasion. It is available in sizes between $\frac{5}{32}$ in. and $\frac{5}{16}$ in. diameter. Its properties of extreme toughness, red hardness, and low friction coefficient make it highly resistant to abrasion at both normal and elevated temperatures. It is economically applied by braze-depositing using a Demon oxy-acetylene blowpipe. This process gives a flawless smooth deposit on any ferrous metal, including stainless steel, but precautions must be taken with high carbon alloy or air-hardened steel. Having a coefficient of linear expansion similar to that of steel, a Sifonite deposition has very low tendency to the formation of shrinkage cracks. Once deposited Sifonite cannot be annealed, forged or hardened, but it can easily be ground with an ordinary aluminium oxide grinding wheel. The Rockwell hardness at 59/61 (C scale) is maintained up to 800° C.

The bronze rod is specially produced for the Sifbronzing of stainless steel fittings, and has an extremely good colour match. It is available from stock in $\frac{3}{16}$ in. and $\frac{1}{4}$ in. diameter sizes.

Suffolk Iron Foundry (1920) Ltd., Sifbronze Works, Stowmarket.

CURRENT LITERATURE

Book Reviews

THE STORY OF THE MUSHETS

By Fred M. Osborn. 8vo. xii + 195 pp. Thomas Nelson & Sons, Ltd. London, 1952. 21s.

It is particularly appropriate that this story of the Mushets should have been written by a member of the firm of Samuel Osborn & Co., Ltd., which was so closely associated with Robert Forester Mushet in making the R. Mushet Special Steel which he invented, and it was fortunate that Fred Osborn was able to complete the script before he died, not only because of the satisfaction he would derive from its completion after about 18 months work on it, but also because of the wealth of information he had been able to gather and assemble in so interesting a manner.

The book is divided into four parts which deal respectively, with David Mushet and his achievements; Robert Forester Mushet and his great contribution to the age of steel; Robert Forester Mushet and his second great contribution to the age of steel; and descendants and ancestors. It includes nine appendices which not only support the research work of the author but add greatly to the interest of the book.

David Mushet, during the last decade of the 18th century, and the first part of the 19th, covered the period which was the peak of the iron age. His early days in industry were as an accountant at the Clyde Iron Works, but he was greatly attracted to the scientific side of blast-furnace practice and used his spare time to carry out experiments. Ultimately, however, the furnace in which he carried out experiments was pulled down. This did not deter him, for he built himself a furnace, the work on which laid the foundation of his reputation as the foremost expert on blast furnace practice, and later his technical papers were recognised as the most valuable contributions to iron manufacture that had yet been given to the world.

David Mushet remained at the Clyde Iron Works until the year 1800, when he went into partnership with William Dixon and Walter Neilson at the Calder Iron Works. As the manager of these works, David Mushet took an active part in reconstructing them. In the following year he discovered the existence of "black band" in 2,000 acres of land, including the Airdrie estate, which contributed greatly to the development of the iron industry in Scotland, but it was a long time before the value of the discovery was realised. This resulted in difficulties at the Calder Iron Works and David Mushet retired from his partnership and with his wife and family journeyed to Alfreton in Derbyshire, where he joined up with the Alfreton Iron Works and undertook experiments on "wootz" or "Indian steel." In 1810 he acquired property in the Forest of Dean and removed from Alfreton to Coleford, where he obtained an interest in the Whitecliff Iron Works. The Forest of Dean subsequently played a very important part in the lives of David Mushet and his son Robert.

As the years passed, the metallurgical activities of the Mushet family were carried on with increasing activity by Robert Forester Mushet. It was Robert who studied the problems associated with the making of cheap steel following on the discovery of the Bessemer process. He had already successfully experimented with spiegeleisen, and by the addition of this material was developed the Bessemer-Mushet process, which made possible the large scale production of cheap steel. But his claim to fame will always be associated with his discovery of self-hardening tool steel, which became known as R. Mushet Special Steel. This was the first self-hardening steel and it was made in the autumn of 1868: in 20 years this steel was established in England and America and, indeed, the world over.

This book makes very interesting reading, particularly the correspondence, which is included, showing the controversy over the part played by Mushet in making possible the production of steel by the Bessemer process. There can be no doubt that the iron and steel industry, not only of this country but throughout the world owes a great debt to the Mushets for their outstanding developments during those earlier days, and this permanent record of their achievements should be read by all interested in steel.

RECENT DEVELOPMENTS AND TRENDS IN IRON AND STEEL TECHNOLOGY

37 pp. duplicated typescript. Published in Geneva by United Nations Economic Commission for Europe.

This report is the first of a series designed to assist businessmen, government officials and professional economists to keep abreast of developments in basic iron and steel making processes. It contains the following papers:—

1. "Possibilities of Development in the Production of Iron," by Professor Robert Durrer of the Zurich Polytechnicum and Director of the Louis de Roll Iron and Steel Works, Switzerland;
2. "Developments in the Iron and Steel Industry of Canada," by Mr. P. E. Cavanagh, Assistant Director, Department of Engineering and Metallurgy, Ontario Research Foundation, Canada;
3. "Trends in Iron and Steelmaking Processes" (with particular reference to Sweden), by Professor Bo Kalling, Director of Research of Domnarvet, Sweden;
4. "The Belgian Iron and Steel Industry in 1951," by Professor A. G. Lefebvre of the Faculté Polytéchnique de Mons, Belgium;
5. "Technical Research Trends in the French Iron and Steel Industry," by Mr. H. Malcor, President of the Institut de Recherches de la Siderurgie, France; and
6. "Technical Progress in German Iron and Steel Production," by Dr. Ing. H. Schwenk of the Verein Deutscher Eisenhuttenleute, Dusseldorf, Germany.

Practically all of the five specialised papers refer to the three main technical developments in the industry: improved ore preparation methods, the use of top pressure in blast furnaces, and the use of oxygen in blast furnaces and in steel making processes.

REPORT OF CONFERENCE ON THE DESIGN OF ROLLING MILLS

Published by the British Iron and Steel Research Association and obtainable from the Association at 11, Park Lane, London, W.1. 51 pp. 11 ins. × 8½ ins. Paper cover. 17 illustrations. 10s. post free.

This report concerns the proceedings of the seventh conference of B.I.S.R.A.'s Plant Engineering Division which had as its topic for discussion the design of rolling mills. The conference was held under the chairmanship of Mr. J. F. R. Jones (Chief Engineer, Construction and Development, John Summers and Sons, Ltd.) and over a hundred delegates (excluding B.I.S.R.A. staff) heard and discussed four papers fully describing the following rolling mill installations in this country.

"The New 42-inch Slabbing Mill at Shotton," by J. F. R. Jones.

"New Blooming and Billet Mills at the Normanby Park Steel Works of John Lysaght's (Scunthorpe Works) Ltd.," by J. A. Peacock.

"A Rod and Bar Mill at Guest Keen and Nettlefolds (South Wales) Ltd., Cardiff," by G. A. Phipps.

"The Light Section Mill at the Darlington Works of the Darlington and Simpson Rolling Mills Co., Ltd.," by W. French.

The delegates represented 48 firms, 12 of them suppliers of steelworks equipment. The full text of the papers and discussions are given in the report.

Trade Publications

The activities of Foundry Services, Ltd., in developing aids to better castings are well-known. They have recently issued copies of revised technical literature which may be obtained on application to the Company at Long Acre, Nechells, Birmingham, 7. This includes leaflets on spray guns, Terracotes (core and mould dressings for ferrous, non-ferrous and light alloy castings), Corfixes (core jointing compounds) and Lomags (for removing magnesium from aluminium alloy). Brochure A describes the Foseco products developed for use with copper and nickel and their alloys, whilst Brochure C deals with Foseco products for iron and steel. A list of the principal Foseco products and "Foseco Overseas" (which gives details of Foseco agents abroad) complete this literature.

We have received from The Fullers' Earth Union, Ltd. Redhill, four pamphlets dealing with the Company's products. "Fullers' Earth" is the name generally reserved for the adsorbent clays, composed mainly of calcium montmorillonite, which have high adsorptive and base-exchange capacities, thixotrophy in aqueous suspension, and exceptional bonding power. The first pamphlet deals with the geology of these clays and discusses their structure and chemical and physical properties, before listing a wide range of industrial operations in which they may be used in the natural or modified state. The chief interest of fullers' earth products in the metallurgical field undoubtedly lies in the use of the manufactured Fullbonds for bonding foundry moulding sands, an application which is dealt with in a second pamphlet which describes their use for reclaiming and strengthening natural and semi-synthetic moulding sands, for bonding synthetic moulding sand mixes, and as a corebinder, usually in conjunction with an organic material. The details of the properties of the various grades given here are supplemented in a further leaflet with properties at higher moisture contents, i.e., with a moisture exceeding 4%. The last leaflet deals with Fulbent, sodium montmorillite made from fullers' earth deposits in this country and possessing the properties of natural sodium montmorillite or bentonite. A metallurgical application of this material is in foundry paints.

We have received from Henry Wiggin and Co., Ltd., Wiggin Street, Birmingham, 16, a copy of the revised edition of their booklet on the Nimonic alloys which was first published a year ago. Detailed properties are given of these high-temperature materials, and readers will note that the creep curve for Nimonic 80A at 700° C. with a load of 7 tons/sq. in. has now been completed, the specimen fracturing at 34,065 hours with a strain of about 1·15%. Although Nimonic 80A was primarily designed for use at high temperatures for short times, the data show that the alloy is also suitable for long term use. The curves published were obtained on material as heat-treated for aircraft service, but investigations are at present in hand to develop the best possible long-time creep properties. Short notes are also included on Nimonic 95, the latest published addition to the series of creep-tested wrought alloys, together with general descriptions of Nimonic DS and Nimonic DT, which are modifications of Nimonic D introduced recently.

Founded in 1859, the original Head Wrightson Company, then known as Head Wright and Company, participated in the historic expansion of the heavy industries which marked the latter half of the nineteenth century. To-day, the activities of the Head Wrightson Group still centre on the design and manufacture of equipment and components for the heavy industries, principally for the winning and processing of coal and oil, iron and steel, and non-ferrous metals. In addition, equipment and components are supplied for ships, railways, automobiles and aircraft, but it is not possible to define with accuracy the precise limits of the Group's activities, so wide is the field of engineering it covers. A recently published illustrated brochure, shows some of the things made by the ten principal divisions and subsidiary companies of the Group.

The latest Wild-Barfield leaflet deals with carbo-nitriding. This process of case-hardening consists of introducing into the steel both carbon and nitrogen from a gaseous atmosphere. The process is ideal for hardening small components of equipment such as typewriters, sewing machines, etc. and small machine parts, including certain small gears, levers, bushes, ratchets, etc. The advantages claimed for the process include improved hardenability; reduced distortion; lower power costs; consistent results; safe, simple and clean operation; increased output; and minimum maintenance. Copies may be obtained from Elecfurn Works, Watford By-pass, Watford, Herts.

Following the publication of their technical circular No. T.C.854 giving general information on Twin-Arc welding, The Quasi-Arc Company, Limited, have published a 24-page instruction book, reference IB.2, giving information on the installation, operation and maintenance of the TA.250 Twin-Arc Welding Plant, and the best Twin-Arc welding techniques for various types of joints. Copies can be obtained on application to The Quasi-Arc Co. Ltd, Bilston, Staffordshire.

METALLURGICAL DIGEST

Better Brass Mill Products Produced by Continuous Casting

By Edward L. Wolff and Frederick M. Barry

PRACTICALLY all metal forms trace their production ancestry back to a casting, the soundness of which, to a large degree, governs the quality of the finished material. Flaws in the casting will show up in the end product—even after rolling, extruding or drawing. Continuous casting minimises such flaws with the result that mill products made from continuously cast brass are sounder and more uniform than products made from individually cast bars or billets.

The advantages of continuous casting from a production standpoint were recognised 100 years ago, and ferrous and non-ferrous producers also agree on the quality advantages of continuously cast metal. The problem has been to design a successful continuous casting machine. The basic apparatus necessary is fairly simple, but there are endless possible difficulties in connection with porosity, shrinkage, skin breakage and grain structure variations inherent in this continuous casting concept.

The first practical solutions were worked out by Siegfried Junghans of Ulm and Stuttgart in Germany before the second world war. Junghans tested every conceivable variation in mould design, pouring speed, temperature and cooling technique. Before the war, continuous casting machines were installed in the plants of several German brass and aluminium producers, and all these machines were commercially successful. Aluminium billets up to 20 in. diameter and cartridge brass bars up to 29 in. × 4 in. in cross section were cast. Junghans, in his own plant, even set up a continuous casting machine with heavy reducing rolls to work the hot metal as it came from the mould.

Many other approaches have been made to continuous casting, only two of which have achieved real commercial stature. The Williams process is being developed jointly by the Republic Steel Corporation and the Babcock and Wilcox Tube Co., while the Rossi process is now in full-scale commercial operation in the United States and in England.

From *Materials and Methods*, April, 1952, 94–97.

The latest type Rossi continuous casting machine and holding furnace unit is designed to handle up to 30,000 lb./hr. of brass. The molten metal is supplied from three induction furnaces, each having a capacity of 10,000 lb./hr. A 5,000-lb. capacity ladle transfers molten metal to the 9,000-lb. capacity electrically heated holding furnace at the top of the machine. This holding furnace has two sets of pouring spouts; if one set becomes clogged, the furnace can be revolved 180° on its mount, tipped in the opposite direction, and poured through the duplicate spout. Each of the down spouts is in the form of an inverted T submerged. The rate of flow through the downspout is controlled by the operator by means of a specially designed needle valve.

The copper mould has a water-cooled jacket and moves up and down with a reciprocating motion. The downstroke of the mould is synchronised with the rate of discharge of the casting and the upstroke is several times that rate. The slab or billet, as the case may be, changes from molten to a dull red solid condition as it passes through this moving mould and is continuously drawn down at controlled constant speed by a pair of withdrawing rolls. Immediately below the rolls, and mounted on a travelling elevator-type platform, is a horizontal circular cut-off saw. When the billet or bar has reached the required length (usually from 2½ to 10 ft.) this saw is automatically advanced to the cutting position, and while cutting, travels down with the moving casting. The cut section descends into a carrier and is automatically lowered and delivered to conveyor tables for removal to stock or for immediate use. One of the continuous casting machines at the works of Scoville Manufacturing Co. delivers a 7¾ in. diameter, 31¼ in. long billet every two minutes. The continuous bar casting machine produces a 2,200 lb. flat slab, 25½ in. wide, 2½ in. thick and 10 ft. long about every six minutes.

The prospects for the development of continuous casting seem to be particularly bright. The following summarises the present position.

Brass. Installations at the mills of Scoville Manufacturing Co. have, since 1938, upwards of half a million tons brass production behind them. Compared with former traditional casting methods, savings of up to $6.00 a ton have been made, and the dependable quality and high output of the Rossi machines have served as one of the basic reasons for a $10 million investment in this Company's new continuous cold-rolled brass strip mill.

Copper. The American Metal Co., through its subsidiary, the United States Metal Refining Co., has been successful during the past year in the continuous casting of oxygen-free, high conductivity copper billets from 6 to 8 in. diameter and slabs 4 in. × 13 in. and 3½ in. × 26 in. in cross-section on a commercial basis.

Aluminium. Aluminium production is another field of tremendous promise for continuous casting. Experimental work has been largely completed, and commercial operation has been going on at the Rossi continuous casting installation in the English plants of Imperial Chemical Industries, Ltd., and James Booth & Co., Ltd. Continued success of this method for the production of aluminium billets up to 20 in. diameter and slabs up to 10 × 48 in. will offer important production advantages over multiple mould methods now used in this industry.

Steel. At Allegheny Ludlum Steel Corporation's Watervliet plant the casting of stainless steel billets—4½ to 9 in. diameter—and bars up to 3 in. × 15 in. in cross-section, by the Rossi process, has been going on for about two years. Metal of such good quality has been produced at low cost that expansion of the operation is being advanced with all possible speed. A new and larger Rossi machine is now contemplated for this plant.

What steel producers can eventually look forward to with full use of continuous casting methods and equipment covers a wide range of needs. Ingot pouring, soaking pits and blooming mill operations, with equipment often costing many millions, can be eliminated almost entirely, since continuous casting will produce metal of dimensions suitable for direct feeding to the rolling mill,

How to Case Harden Steel by Nitriding

By John L. Everhart

THE nitriding process depends for its effectiveness on the formation of nitrides in the steel by the reaction of nitrogen with certain alloying constituents. There are two basic requirements. A nitride forming element must be present and the nitrogen must be supplied to the surface in atomic form: ordinary molecular nitrogen will not nitride steel. In the original process, the steel is exposed to gaseous ammonia at a suitable temperature for the formation of the metallic nitrides. The material to be nitrided must be placed in a closed container with means supplied for the continuous circulation of ammonia. No special furnace is needed, although it is necessary that the furnace be capable of maintaining uniform heating conditions for the time required to complete the operation. The temperatures are maintained generally in the range 930–1,050° F. (500–565° C.), and the operation requires up to 90 hours for completion.

Upon exposure of the steel to ammonia in this temperature range, part of the ammonia breaks down into atomic nitrogen and hydrogen, the former attacking the steel to form nitrides. Usually conditions are adjusted to obtain 30% decomposition of the ammonia. The case thus formed on the steel consists of two layers: the outer or "white layer" which is softer and is usually removed by grinding after nitriding. The inner layer contains precipitated nitrides formed by diffusion inward of the nitrogen from the white layer. Being a diffusion process the depth of case depends on the time of exposure to the nitrogen. With suitable equipment, this method of nitriding is readily controllable and is the most widely used process at present.

A modification of the process has been developed by Floe for applications where grinding off the white layer is undesirable or impracticable. This is a two-stage nitriding cycle in which the ammonia dissociation is held at 20% for a period of 5 to 10 hours at 975° F. (525° C.). The temperature is then increased to 1,025–1,050° F. (550–565° C.) and the ammonia dissociation to 80–85%. During the second stage, any white layer which has been formed on the surface is removed by inward diffusion of the nitrogen. Thus, the final case is practically free of a white layer and ready for service immediately. This process is being increasingly employed for such applications as gears where the elimination of a finishing operation reduces the cost.

From *Materials and Methods*, May, 1952, 90–93.

A second method consists of heating the steel in a suitable salt bath maintained in the same temperature range as that used for gaseous nitriding. Although a number of compositions are in use, they are all variations of the basic mixture of 60% sodium cyanide–40% potassium cyanide. This procedure has been claimed to be more rapid than gaseous nitriding because of more intimate contact of the nitrogen with the steel, but this point is somewhat controversial for, being a diffusion process, the rate of penetration is determined by the composition of the steel. This process is particularly advantageous for nitriding small lots of material and is frequently used for the application of thin cases on tool steels. Ease of temperature control is another advantage of this process.

The principal elements which contribute to the formation of useful nitride cases are aluminium, chromium, molybdenum, vanadium, tungsten and titanium. Other elements, such as carbon, silicon and nickel, do not form nitrides but can influence the type of case by obstructing the rate of penetration of the nitrogen and thus reducing the case depth. Carbon can also influence the case by forming carbides with elements such as chromium and removing them from the reaction.

The hardest cases are obtained with aluminium-bearing steels, and a special class of steels, the Nitralloys, which contain this element are widely used for nitriding. The Nitralloys are generally medium carbon steels containing also chromium and molybdenum, the latter being particularly effective in preventing the embrittlement which can occur in steels heated in the nitriding range. One of the alloys in this group contains 3½% nickel. Nickel and aluminium together form a precipitation hardening steel and the optimum temperature for this reaction is the same as that ordinarily used for nitriding. Thus it is possible to obtain increased hardness and strength in the core during nitriding, although with some loss in ductility. With the other steels in this group, the core properties remain practically unchanged during nitriding. The maximum case hardness is obtainable with the Nitralloy steels, but, for some applications, somewhat lower hardness is desirable and steels containing no aluminium are used. All stainless steels can be case hardened by nitriding, and a number of them are used for this purpose.

The nitriding operation is performed at a relatively low temperature and no quenching is required. Distortion is reduced to a minimum, a factor which permits the finishing of parts to close tolerances before nitriding. This is one of the advantages of nitriding over carburising. Some complex parts, which cannot be case hardened satisfactorily by carburising, can be nitrided without difficulty.

Wear resistance is an outstanding characteristic of the nitrided case and is the factor influencing its selection in most applications. The hardness of the nitrided case is unaffected by heating to temperatures below the original nitriding temperature, and substantial hardness is retained up to at least 1,150° F. (620° C.). This is in marked contrast with the carburised case which begins to lose its hardness at relatively low temperatures. The retention of hardness is credited with being one of the major factors contributing to the wear resistance of nitrided steels.

Fatigue resistance is also one of the valuable features of nitrided steels. Favourable fatigue properties are credited to the fact that the nitrided layer is in compression, a condition very favourable for resistance to alternating stresses. Numerous tests have shown that fatigue failure in nitrided steels tested to destruction originates near the boundary between the case and core, since this is the region of highest tensile stress. As a result, designing for applications of nitriding steel is usually based on the fatigue strength of the core rather than that of the case.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC

INSTRUMENTS AND MATERIALS

OCTOBER, 1952 Vol. XLVI, No. 276

Developments in the "Dead-Stop End Point" Titration Technique

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Although the "dead-stop end point" technique has been in use for over a quarter of a century, it is only recently that the theoretical principles involved have received much attention. Interest in the practical aspects has not diminished, various new titrations for the determination of metals and other substances having been developed during the past few years. An apparatus for automatic dead-stop titration has also appeared.

OVER 25 years have now elapsed since the United States workers, Foulk and Bawden, described their simple and elegant "dead-stop end point" technique[1]. Nevertheless, a survey of recent scientific literature shows that the interest, both in the theoretical and in the practical aspects of the method, is certainly not diminishing. As has been previously pointed out[2] the method is often particularly suitable for the determination of substances present in low concentrations. In this connection the determination of microgram-quantities of metallic silver in, for example, exposed photographic emulsions may be instanced. The method involves an arsenite-iodine titration; using the dead-stop technique, Lambert and Walker[3] were able to employ 0·0001N solutions and reported that 5-microgram quantities of silver could be determined to ± 1%. In some cases the dead-stop method is successful when potentiometric technique is unsuitable.

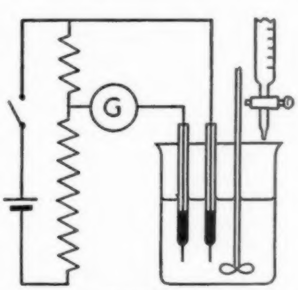

Fig. 1.—Circuit arrangement for dead-stop end point titration.

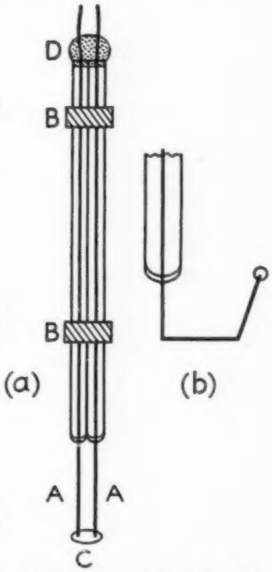

Fig. 2.—Electrode-system for titration of small volumes of solution.

Apparatus

The essential electrical equipment is shown in Fig. 1 and is very simple. Across two electrodes which dip into the solution to be titrated is applied a small fixed e.m.f., often of a few millivolts only. A sensitive galvanometer, usually of mirror type and having a sensitivity of from 50 to 200 mm. per microampere is inserted in one of the leads to the electrodes. In certain kinds of titration, almost zero current flows through the solution until the end point is reached. Addition of a slight excess of reagent then causes a large permanent deflection of the galvanometer. Sometimes the initially large galvanometer deflection falls abruptly at the end point, whilst in other cases this point is marked by an abrupt change from falling to rising current.

Small platinum plates or wires sealed into short lengths of glass tubing form electrodes suitable for most cases. For the titration of small volumes of solution[4] the electrode system originally developed for micro-conductometric titration[5] may be useful. A piece of platinum wire is threaded through a length of melting-point tubing and sealed in at one end, so that about 10 mm. of wire projects from the closed end, as shown at (*a*) in Fig. 2. A second electrode is prepared in the same fashion. The two electrodes *AA* are then placed side-by-side and held together by slipping on short lengths of cycle valve tubing *BB*. Having made sure that the wires projecting from the seals are straight and parallel, a bead of glass *C* is fused across the extremities. The free ends of the wires are snipped off fairly close to the open ends of the tubes and copper connecting leads are soldered on. A blob of sealing wax *D* not only prevents short circuiting but also the entry of moisture into the tubes. By bending as shown in enlarged side view (*b*), the electrodes may be used when the depth of solution is small. Although electrodes for conductometry are usually platinised, they are left bright for dead-stop work.

Since the introduction of the dead-stop end point technique coincided with a period in which interest in radio and the like was swiftly rising, it was not long

before electronic devices were pressed into service. A "magic eye" radio tuning indicator may be used in place of the rather fragile galvanometer, rendering the apparatus much more suitable for routine use. Improved instruments of this kind have recently been described[6,7].

An interesting mains-operated automatic titration apparatus, designed especially for the determination of moisture by the Karl Fischer method (*vide infra*) has been described by Frediani[8]. The apparatus is being marketed under a pending U.S. patent by Beckman Instruments, Inc., of California. A solenoid-operated valve is fitted to the burette and a timing mechanism enables true and false end points to be differentiated. Fig. 3 illustrates the principles involved; the actual instrument incorporates additional controls, notably a switching device which brings in a second set of relay contacts and permits direct or back titration at will. A step-down transformer *A* coupled to full-wave selenium disc rectifier *B* supplies direct current for operating the relays and for applying the polarising potential: the latter is adjusted by control *C*. On switching on, the burette valve *D* will open and the titration will commence. As the end point is approached, momentary accumulation of reagent causes a temporary increase in the current, which is indicated by microammeter *E*. Each time the current exceeds a given value, e.g., 50 microamperes (preset by a control not shown), the contacts of sensitive relay *F* close. In turn, the power relay *G* becomes energised, causing the flow of titrant to cease and simultaneously starting the motor of timer unit *H*. If the current drops rapidly, the relay contacts revert to their original position, restarting the flow of reagent and switching off the timer unit. The latter resets itself to zero. These operations are repeated until the true end point is reached; the timer motor then runs for its full preset period (variable from 0 to 60 seconds) and then operates a micro-switch, thus permanently cutting off the burette valve. At the same time a "read burette" lamp (not shown in Fig. 3) lights up. Straightforward titrations may be completed in 30 to 60 seconds. Samples which release moisture slowly and hence show numerous false end points can be rapidly and precisely titrated.

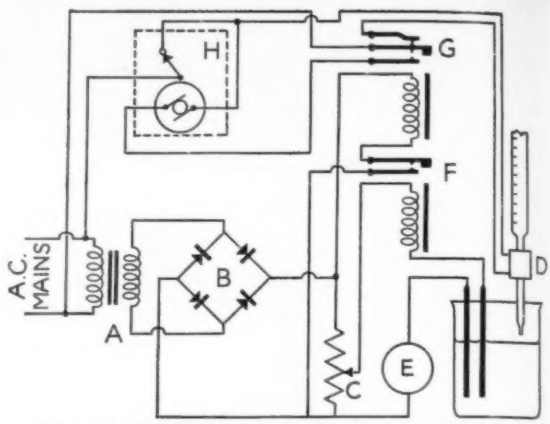

Fig. 3.—Automatic dead-stop titration apparatus.

Theoretical Aspects

The characteristic on-off nature of the dead-stop end point was originally ascribed to adsorption of hydrogen and oxygen on the respective electrodes. Even if only one of the electrodes became thus polarised, the current flowing would fall to a negligible value. Destruction of the polarisation, occurring at the end-point, permits an abrupt increase in the current and a consequent permanent galvanometer deflection. It was not until 1942 that explanations of this kind were questioned. Böttger and Forche[9] then suggested that an applied e.m.f. of 15 millivolts, as used by Foulk and Bawden, was inadequate for hydrogen-formation on the cathode. Using a divided-cell technique they were able to show the occurrence of a variation of electrode potential with concentration.

An interesting theory, based on the fact that oxidation-reduction processes may be either reversible or irreversible, has been put forward by Delahay[10]. He points out that if a small voltage is applied to the platinum electrodes dipping into the solution, current will flow if the system is reversible (e.g., iodine-iodide), oxidation occurring at one electrode while reduction is taking place at the other. Provided that concentration polarisation does not occur, the current-flow will increase linearly with the applied voltage, as shown at (*a*) in Fig. 4. Where an irreversible system (e.g.. thiosulphate-tetrathionate) is involved, the oxidation and reduction processes require overvoltages which may be of the order of one volt. While this system persists, current will not flow unless the potential difference is larger than the sum of the overvoltages [Fig. 4(*b*)]. Delahay concludes that redox titrations are possible by the dead-stop method provided that *either* the reagent *or* the solution to be titrated is an irreversible redox couple. Where reagent and sample solution are both reversible, the method will be inapplicable.

The contention that the method cannot be applied to redox titration processes in which both systems are reversible, has been questioned almost simultaneously and apparently quite independently by workers on both sides of the Atlantic. Kies[11] considers that an end point should be obtainable and that it should be indicated as the lowest point of a V-shaped current-volume curve. On titrating a solution of potassium iodide containing a large excess of potassium bromide with bromine water he obtained a current-volume curve of the type shown in Fig. 5. Despite that the reaction $I^- + Br_3^- \rightleftharpoons IBr_2^- + Br^-$ does not involve irreversible processes there is no doubt that a well-defined end point is obtainable. Using potassium bromate and acid as a source of bromine, he treated potassium iodide solutions with 1/3, 2/3, 3/3, and 4/3 equivalents of potassium bromate and examined each polarographically using a rotating platinum electrode. In the case of the 3/3 sample only the polarogram showed a plateau at almost zero current, corresponding with the end point obtained in actual titration experiments.

Stone and Scholten[12] performed a series of dead-stop titrations measuring not only the current flowing but also the potential of each electrode by reference to a saturated calomel electrode also dipping into the solution. The titrations studied included, among others, those of ferrous sulphate, potassium ferrocyanide and titanous sulphate with ceric sulphate and potassium permanganate. Fig. 6 indicates the typical behaviour in the vicinity of the end point of the titration of ferrocyanide with ceric sulphate, the complete current-volume curve having the same general form as that reported by Kies (Fig. 5).

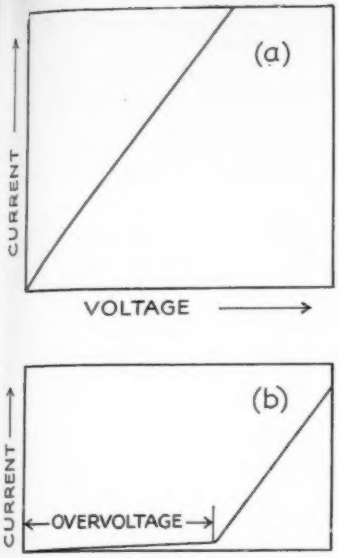

Fig. 4.—Current-voltage curves for (a) reversible, and (b) irreversible oxidation-reduction systems.

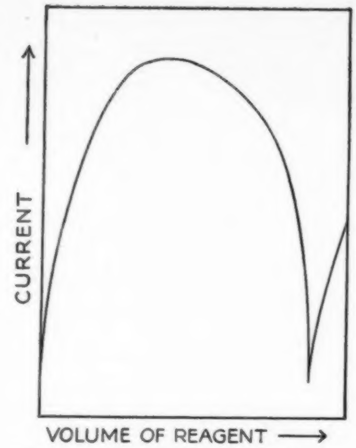

Fig. 5.—Curve for redox titration in which both systems are reversible.

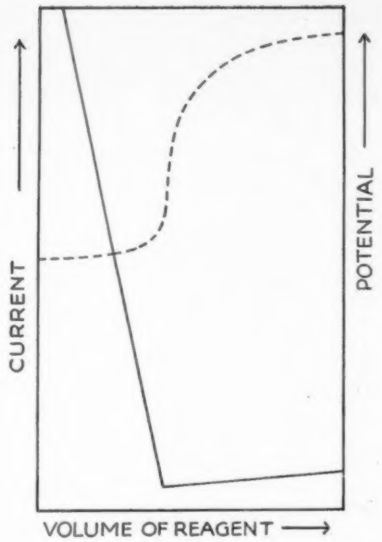

Fig. 6.—Variation of current (full line) and of electrode potential (broken line) in a typical redox titration.

Stone and Scholten conclude that the end point in a dead-stop titration depends upon electrolytic oxidation at the anode coupled with electrolytic reduction at the cathode. In the titration of, for example, ferrous sulphate solution, the current flowing will be governed not only by the availability of ferrous ions for oxidation at the anode, but also by the availability of ferric ions (initially present in neglible concentration only) to be reduced at the cathode. When an oxidising agent such as ceric sulphate is added from the burette, the current rises as the supply of ferric ions is increased. Thereafter, the decreasing availability of ferrous ions on further addition of oxidising agent becomes a controlling factor, causing the current to fall progressively until the end point is reached. Continued titration beyond the end point introduces ceric ions into a solution containing an ample supply of cerous ions; the current therefore rises again.

Many of the titrations studied by Stone and Scholten were achieved using an applied e.m.f. of 50–100 millivolts. These workers point out that changing the potential changes only the sensitivity and not the location of the end point.

Determination of Metals

Stannous tin in 0·1M hydrochloric acid may be titrated iodometrically if the solutions are properly deoxygenated[13]. Peculiarly enough, carbon dioxide direct from the cylinder was found much more satisfactory for deoxygenation than nitrogen which had been purified by passage through alkaline pyrogallol or Fieser's solution. With 50 millivolts applied to the electrodes, a small initial galvanometer deflection, permanently increased by the first excess of iodine, is observed. Duplicate 10-ml. titrations of 0·005M stannous chloride agreed to 1–2 parts per 1,000.

Although a sluggish end point is obtained below 60° C., the titration of zinc with potassium ferrocyanide solution may be rapidly performed at about 70° C.[13]. In order to obtain a sharp end point, the zinc solutions should contain ammonium sulphate; about 2 grams of this substance and 2 ml. of 6N sulphuric acid in 100 ml. of solution were found satisfactory. The application to the electrodes of 200 millivolts is recommended, when zinc sulphate in concentrations down to 0·005M may be titrated with a precision of 1–2 parts per 1,000. By stopping at an arbitrarily chosen galvanometer deflection, solutions as dilute as 0·001M may be titrated, but the end point is no longer sharp. On the other hand, more concentrated solutions (e g., 0·1M) of zinc sulphate may be titrated using a rugged type of meter. The results are as good as with sodium diphenylamine sulphate indicator.

Gale and Mosher[14] found that milligram-quantities of vanadium in the presence of uranium and in the possible presence of iron, titanium and chromium may be titrated at 5° C. with ferrous ammonium sulphate solution. The platinum electrodes are occasionally sensitised by immersion in hot chromic acid and a microammeter having a full scale reading of 20 microamperes replaces the usual galvanometer. Trial runs in the presence of 100–1,000 mg. of uranium, 10 mg. of chromium and 10 mg. of titanium showed that quantities of about 4 mg. of vanadium could be determined to better than 1%.

In his studies on the use of potassium bromate in volumetric analysis, G. F. Smith has investigated the determination of arsenic and antimony. He found that end point detection by the polarised platinum-platinum electrode pair is precise and convenient[15].

Moisture Determination

Determination of water by use of the Karl Fischer reagent continues to be the subject of numerous publications, including an important monograph[16]. Although in favourable cases the titration may be followed visually, use of the dead-stop technique is now more usual. Lewis has described its use in the examination

of liquid sulphur dioxide containing 0·0005 to 0·001% of water[17], while Rennie and Markham applied it in the determination of moisture in gunpowders, glacial acetic acid, shellac solutions, and sawdust[18]. The dead-stop Karl Fischer technique has proved similarly useful in the examination of a variety of other substances, such as dehydrated foodstuffs[19], dried egg-white and other protein materials[20], oils and greases[21], digitalis and other vegetable drugs[22], nylon[23], and dihydrostreptomycin[8].

Organic Applications

The volumetric determination of reducing sugars by running the solution into boiling standard Fehling's solution may be followed by the dead-stop technique. The process described by Coalstad[24] is interesting in that electrodes of 10 s.w.g. copper wire were used in place of the usual platinum ones. This worker reported a sharp, reproducible end point, at which the galvanometer reading swings almost to zero. Bell and Graham[25] had no success with this electrode arrangement, but reported good results with a copper anode and a platinum cathode. This use of a dissimilar-metal electrode pair (for dead-stop work) is reminiscent of the early work of Brann and Clapp [26] on the Volhard titration of manganese, in which a silver anode and a platinum cathode were found necessary. (The use of dissimilar-metal electrode pairs in potentiometric titration has, of course, been studied quite extensively[27].)

Two independent studies on the bromometric measurement of olefinic unsaturation in hydrocarbons such as petroleum products have been reported. Dubois and Skoog[28] described the titration with bromate-bromide solution, while Braae[29] uses bromine dissolved in carbon tetrachloride. In both cases mercuric chloride proved to be a satisfactory catalyst, as did a dead-stop apparatus of the " magic eye " type. The determination of iodine numbers by dead-stop titrimetry agrees well with normal methods[30].

If a precision of 1% is sufficient, 8-hydroxyquinoline in a solution containing at least 10% of hydrochloric acid may be directly titrated with bromine[31]. The addition of excess bromine, followed by arsenite back titration, is reported to give greater precision.

A very sharp end point is obtained in the bromometric titration of procaine sulphanilamide, and related compounds[32]. An aliquot containing about 5 mg. of the substance is titrated with potassium bromate solution after the addition of potassium bromide and hydrochloric acid.

The determination of primary aromatic amines by titration in dilute hydrochloric acid with sodium nitrite solution has been studied by Scholten and Stone[33]. Potassium bromide is used as a catalyst, but the end point is not very sensitive and is sluggish compared with other dead-stop end points. The use of the unusually high applied e.m.f. of 0·4 volt in this titration is interesting.

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A Semi-Quantitative Spot Test for Tin in Magnesium and Aluminium Alloys

Continued from page 216

acid, cool if necessary to control the violence of the reaction, and complete the reaction by immersion for a short time in a water bath at about 60° C., until the sample dissolves completely, or until the insolubles (e.g. silicon and copper) settle to the bottom. Avoid unnecessary delay because of the risk of reoxidation. Suck up part of the clear solution or supernatant liquid in a teat pipette.

Place one drop of the starch-iodine reagent (solution No. 6*a*) in the depression of a spot plate and add the metal solution, drop by drop, until the reagent is decolorised, noting the number of drops required. Stir after each drop and do not wait longer than about five seconds after adding each drop before judging the result.

The quantitative interpretation of the test is based on controls with standard samples or synthetic standard solutions of pure aluminium with added standard stannous solution. A typical series is summarised in Table I.

Complete decolorisation after the first drop of metal solution indicates 0·5% of tin *or more*.

If it is desired to evaluate contents above 0·5%, add to the above mixture further drops of the reagent 6a until the colour persists, and estimate the tin content by the number of drops required, on the basis of two drops of starch-iodine reagent indicating 1% of tin. This ratio was found to hold good for contents up to 30% of tin.

The degree of accuracy can be seen from Table II which gives the results of a series of practical tests. The operator did not know the content of the samples which were tested at random and only afterwards grouped in order of tin content ; no result has been omitted. It is obvious that the quantitative significance of the single drop is greater when the number of drops is small, and that the percentage accuracy is, in such cases, diminished.

Acknowledgments

These experiments were carried out in the laboratories of International Alloys Ltd., Aylesbury, Bucks., and the authors wish to thank the Directors of the Company for permission to publish.

A Note on the Comparison of Some Simple Condensed Spark Circuits in the Spectrographic Analysis of Aluminium and Magnesium Alloys and Pure Magnesium

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As the result of an investigation of the relative performance of simple condensed spark circuits in the spectrographic analysis of aluminium and magnesium alloys and pure magnesium, it is concluded that, although it is possible to grade the results on the basis of reproducibilities, the type of source unit does not have a major effect on the precision attainable.

SINCE the establishment of spectrographic analysis as a means of analytical control, continuous work has been going on to try to improve the accuracy, reproducibility and speed of this technique. Each aspect has been studied in turn (photographic, sampling, etc.) with particular reference to its contribution to the total error obtained. In recent years, source unit design and the application of photoelectric measurement, have received considerable attention. With particular reference to source units, the general trend seems to be in favour of more complicated designs, usually with a view to obtaining more stable discharges and so, presumably, contributing less to the total error of analysis.

From 1937, uncontrolled, simple condensed spark units have been in constant use in High Duty Alloys' laboratories. More recently, with the considerable increase in the number of elements analysed and the wider variety of alloys involved, it was thought necessary to investigate the *relative* performance of the simple circuits available or easily constructed in the company, as applied to aluminium and magnesium alloys and pure magnesium. In conjunction with the above, certain work was also carried out using the B.N.F.M.R.A. General Purpose source unit.[1]

It was thought that a summary of some of these results might be of general interest.

The following simple units were included in the experiments :—

(*a*) Hilger-type uncontrolled condensed spark, utilising a Hilger F.282, 0·25 kW., 15 kV. transformer, with provision for the addition of capacity, inductance and resistance as required.

(*b*) Hilger-type uncontrolled condensed spark with the introduction of a tandem gap.

(*c*) Feussner unit used as an uncontrolled condensed spark, i.e. with the synchronous rotary interrupter shorted out.

(*d*) Feussner unit with the synchronous rotary interrupter in use to ensure a "timed spark."

For the quali-quantitative examination of pure magnesium, the D.C. arc was included in the experiments.

Tests on Alloys

For these tests, three standard aluminium alloys and five standard magnesium alloys covering the ranges given in Table I were used.

TABLE I.—PERCENTAGE COMPOSITIONS OF STANDARD ALLOYS USED.

Element	Aluminium Base			Magnesium Base					
	SP 483	SP 484	SP 485	SP486	SP 451	SP 452	SP 453	SP 510	SP 432
Copper	1·55	2·57	3·57	(0·35)	0·27	0·14	0·05	(0·34)	—
Iron	0·40	0·88	1·39	—	—	—	—	—	—
Magnesium ..	1·31	0·78	0·38	Base	Base	Base	Base	Base	Base
Silicon	1·52	0·92	0·37	(0·96)	0·21	0·14	0·06	(0·35)	—
Manganese ..	0·31	0·50	0·72	—	0·33	0·27	0·13	0·06	—
Titanium ..	0·20	0·15	0·06	—	—	—	—	—	—
Nickel	1·43	0·92	0·42	—	—	—	—	—	—
Aluminium ..	Base	Base	Base	5·05	7·18	8·53	9·45	11·79	12·24
Zinc	—	—	—	0·54	0·97	0·62	0·18	1·10	—

Preliminary tests were carried out with each source unit to find suitable electrical settings giving reproducible photographic density measurements which came on the linear, or almost linear, portions of the gamma curves. The spectrograph and electrode (metal pencils used as self-electrodes) conditions were the same in all cases and were those found in earlier work to have the most general application to the analysis of aluminium and magnesium alloys. Plates from a single batch were used to ensure a reasonably constant gamma. The use of stepped filters was avoided. *The only variable, apart from the source unit settings, was thus the exposure time* and this was dependent on the spectral intensity produced by the unit under the selected electrical conditions. One spectroscopist carried out all the tests.

Each aluminium standard was sparked 25 times and each magnesium standard 15 times, in sets of 5 sparkings, which were distributed evenly over the plates. Several plates were sparked. The lines were measured on the Hilger non-recording microphotometer and the direct ratio of the readings for the line pairs (base line and element line) calculated. Calibration graphs were constructed for the respective alloys, using the average of 25 ratios from each of the three aluminium alloys and the average of 15 ratios from each of the 5 magnesium alloys. The individual results were then read off the appropriate calibration graph. From these, the standard deviations and hence the percentage standard deviations (coefficients of variation) were calculated.*

A summary of results obtained is shown in Table II which gives the average percentage standard deviation for each element on each source unit.

* Standard deviation

$$(\sigma)=\left[\frac{(x_1-\bar{x})^2+(x_2-\bar{x})^2+ \text{———} (x_n-\bar{x})^2}{n-1}\right]^{\frac{1}{2}}$$

where n = number of observed results (x_1, x_2 ——— x_n)

and $\bar{x}$ = the arithmetic mean of the results $\left[\frac{x_1+x_2+x_3+ \text{———} +x_n}{n}\right]$

1 *Metal Spectroscopy*, by F. Twyman (1951) (Griffin), p. 224.

Also included in the table are some results obtained using the modified version of the B.N.F. General Purpose unit incorporating the Hilger F.282 transformer, with low capacity, low inductance and high resistance in the discharge circuit. It should be noted that these may not necessarily be the best results obtainable from the unit. Better results may possibly be obtained by the use of alternative line pairs, higher capacity in the discharge circuit and/or the use of graphite counter electrodes instead of alloy self electrodes. It is hoped to continue with this experimental work at a later date.

Observations

It is considered that a reasonable assessment of the relative merits of each source unit of the simple type, for the individual alloying elements, is given by the average results in Table II. The average results for all elements recorded in the last column is considered a good indication of the overall efficiencies of the respective units, using the same general technique and operated by the same spectroscopist.

It is seen from the above experiments that the simple condensed spark unit employing a Hilger F.282 transformer, gives the best overall result. Controlling the analytical gap discharge of a simple condensed spark circuit by means of (*a*) an auxilliary gap, and (*b*) a synchronous rotary interrupter, lowers the order of reproducibility slightly. This confirms and extends the observations originally made by Frommer[2], *viz*: "We have not been able to find any superiority of the Feussner spark generator (with interrupter in operation) as regards the estimation of magnesium in aluminium alloys. This does not, of course, exclude the possibility that it may have some advantage for other constituents or other alloys."

The results obtained using the modified B.N.F. General Purpose unit are of interest. With the low capacity of 10μF, the trigger control and analytical gap currents (RF) were almost identical, and the excitation of the pencils is almost entirely due to the flow through of current from the triggering circuit. The analytical gap components have but little effect and the degree of excitation is similar to that obtained with a simple, high voltage, condensed spark source. Under these conditions the reproducibility obtained is of the same order as for the simple circuits.

A number of tests on Dural standards were included using the Hilger and Feussner uncontrolled spark sources, the main difference being in their transformer characteristics. The results are given in Table III.

Finally, the performance of each of the four simple units and the D.C. arc were tested for the estimation of impurities in 99·9% magnesium, where sensitivity, rather than reproducibility, is the essential criterion. The three standards used in these tests were sparked as self electrodes and in turn against each other. The maximum and minimum impurities in these standards are shown in Table IV.

The plates were examined to ascertain the minimum amounts of each impurity detectable and the ease with which the various amounts of each impurity could be distinguished. Stepped filters were used.

Of the five simple source units tested, the Hilger condensed spark with a tandem gap gave the best results.

2 *Journal of Inst. of Metals*, **LXIV** (1939), p. 396.

TABLE II.—AVERAGE PERCENTAGE STANDARD DEVIATION FOR EACH ELEMENT.

	Source Unit	Aluminium Alloys							
		Mg	Fe	Si	Mn	Cu	Ni	Ti	All Elements
A	Hilger type uncontrolled spark	4·34	2·99	3·51	2·35	5·48	4·47	3·30	3·78
B	Feussner uncontrolled spark	4·54	2·99	3·76	2·56	5·69	5·05	3·69	4·04
C	Hilger type with tandem spark	5·92	3·31	4·04	2·33	6·57	5·62	3·34	4·45
D	Feussner with interrupter	4·95	3·58	4·32	2·89	5·12	5·05	4·24	4·31
E	B.N.F. General Purpose unit	4·72	3·14	4·36	2·32	6·00	6·31	3·50	4·33
		Magnesium Alloys							
		Al	Zn	Mn	Cu	Si			All Elements
A	Hilger type uncontrolled spark	2·44	3·55	3·31	4·88	4·44			3·72
B	Feussner uncontrolled spark	2·92	3·16	5·17	4·92	5·17			4·27
C	Hilger type with tandem Gap	2·64	3·44	4·82	7·21	5·35			4·69
D	Feussner with interrupter	4·01	3·31	5·54	5·79	6·04			4·94
E	B.N.F. General Purpose Unit	2·45	3·90	3·67	4·93	3·89			3·77

All the lower limits of impurities noted in Table IV could be easily detected and the background density was most tolerable, being considerably less than that given by the D.C. arc. The background density of the latter was sufficiently high to make the detection and estimation of most of the impurities impossible. With the simple spark source units, other than the Hilger with a tandem gap, it was possible to detect all the lower limits; but those of zinc, nickel and lead, only with difficulty.

Good results were also obtained with the B.N.F. General Purpose unit, the lower limits being easily detectable, and it is expected that this unit will be of great value in the detection and determination of trace amounts.

Conclusions

From the above short study the following conclusions may be drawn.

(1) Simple uncontrolled or "free running" condensed spark circuits give superior reproducibilities in the analysis of aluminium and magnesium alloys to those given by condensed spark circuits controlled by an auxilliary gap or synchronous interrupter.

(2) A simple uncontrolled condensed spark unit employing a Hilger F.282 transformer gives better results than a Feussner unit, with the interrupter shorted out. This is probably due to different transformer characteristics.

(3) For the estimation of impurities in 99·9% purity magnesium, whereas the direct current arc is not readily applicable, using simple units, the greatest

TABLE III.—AVERAGE PERCENTAGE STANDARD DEVIATION ON DURAL STANDARDS.

	Source Unit	Mg	Fe	Si	Mn	Ni	Ti	All Elements
A	Hilger type uncontrolled spark	3·24	3·57	3·43	2·09	6·94	2·59	3·64
B	Feussner uncontrolled spark	4·24	3·92	4·90	2·94	8·93	2·68	4·60

TABLE IV.—MAXIMUM AND MINIMUM PERCENTAGE CONTENTS OF MAGNESIUM STANDARDS.

	Al	Mn	Zn	Si	Cu	Pb	Ni	Fe
Maximum ..	0·05	0·077	0·030	0·019	0·033	0·034	0·0078	0·0345
Minimum ..	0·003	0·0039	0·007	0·0035	0·0005	0·003	0·0007	0·0135

sensitivity is obtained by the simple condensed spark incorporating a tandem (Zehden) gap. (The B.N.F. General Purpose unit is, of course, extremely suitable for this type of work.)

(4) Used under the conditions stated the B.N.F. General Purpose unit gives reproducibilities of the same order as the simple units.

(5) Although in the above experiments it is possible to grade the results on the basis of reproducibilities, from the evidence available it would appear that the type of source unit does not have a *major* effect on the precision attainable. The homogeneity of the standards used, the selection, measurement and co-ordinating of the spectral lines, are other factors affecting this; homogeneity is probably of the greatest single significance.

Acknowledgment

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A Semi-Quantitative Spot Test for Tin in Magnesium and Aluminium Alloys

By J. Clark and W. Stross

A rapid and semi-quantitative spot test for the estimation of tin in magnesium and aluminium alloys is described, based on the decolorisation of the starch iodine reagent of Charlot and Bézier.

TIN is an unwanted impurity in the majority of light alloys, with a permissible maximum as low as 0·04% in many specifications, although in others it is somewhat higher (0·05–0·1%) whilst in B.S.S. 4L11 it is as high as 1%.

In the important magnesium alloy D.T.D. 350A tin is, however, an essential constituent, being present in the range 4·5–7·5%, and this alone makes it imperative to segregate scrap carefully with respect to its tin content, apart from other possibilities of tin-pick-up. Some form of rapid test for tin is, therefore, desirable.

Spot tests for tin have been published for various alloys[1,2], but a number of these are rather difficult to carry out and interpret, particularly by semi- and unskilled scrap sorters. Furthermore, many are restricted to positive or negative results, whereas it is advantageous to obtain an estimate of the tin content.

Charlot and Bézier[3] published a spot test for tin, based on the decolorisation of the blue starch-iodine complex by the stannous ion (obtained by reduction with iron powder) under conditions making the test highly specific for tin. The present authors have shown that this principle can be used for the rapid classification of the tin content of magnesium and aluminium alloys, using the modified technique described below.

Reagents and Apparatus Required

(1) *N/10 Iodine Solution.*

(2) *Hydrochloric Acid* (1 : 1).—Dilute acid of S.G. 1·18 with an equal volume of water.

(3) *Hydrochloric Acid* (2 : 1).—Dilute two volumes of the 1·18 S.G. acid with one volume of water.

(4) *Saturated Aqueous Solution of Sodium Chloride.*

(5) *Starch Solution* (5%).—The following solution, which keeps indefinitely,[4] has been found most advantageous; it can also be used, apart from this test, for most iodometric titrations, in place of the ordinary unstable solution. Bring to the boil, in a beaker or conical flask marked at the 100 ml. level, 60 ml. of the saturated sodium chloride solution. When it is boiling vigorously, pour into it with stirring, and so slowly that it does not go off the boil, a starch suspension made by stirring into the form of a thin paste 5g. of soluble Lintner starch and 30 ml. of cold saturated sodium chloride solution. Wash the residual starch into the boiling solution with a few millilitres of saturated sodium chloride solution. Boil for a few minutes, make up to the 100 ml. mark with salt solution, mix and pour, whilst hot, on a pleated Whatman 541 filter large enough to take the whole volume of liquid. Cool and bottle. Salt crystals tend to deposit on standing but are not harmful.

Aqueous 5% starch solution can also be used but it keeps for only one or two days.

(6) *Starch-Iodine Reagents.*—These should be freshly prepared each day and shaken before use.

(*a*) *Sensitive Reagent.*—Mix, in order, 1 ml. of the 5% starch solution (No. 5), 18·8 ml. of water and 0·2 ml. of the N/10 iodine solution (No. 1);

(*b*) *Less Sensitive Reagent.*—Mix, in order, 5 ml. of the starch solution, 14·2 ml. of water and 0·8 ml. of the iodine solution.

(7) *Standard Teat Pipettes* (*Droppers*).—The following method of manufacture is adopted so that drops of uniform size are delivered by all the pipettes. Pull out a piece of glass tubing over a flame and pass the capillary part through a hole (e.g. of 0·11 in. diameter*) in a piece of metal sheet (e.g. 0·08 in. thick) until it cannot be pushed any further; cut it at this point with a sharp cut. Unstandardised droppers may be used if the same dropper is used throughout, but the necessary frequent washing, drying or rinsing makes them less convenient.

Procedure

A. Magnesium Alloys.

Prepare a clean surface, e.g. by drilling to a depth of 1 or 2 mm. with a twist drill of approximately ⅜ in. (9 mm.) diameter, thus forming a little cup to take a

1 B. S. Evans and D. G. Higgs. *Analyst*, (*a*) 1946, **71**, 466; (*b*) 1950, **75**, 193; (*c*) 1947, **72**, 103; (*d*) Spot-tests for the Identification of Certain Metallic Coatings and of Certain Metals in Bulk. Published for The Society of Public Analysts by W. Heffer and Sons, Ltd., Cambridge.

2 F. Feigl. (*a*) "Manual of Spot Tests," 1943, Academic Press Inc., New York, pp. 101–103; (*b*) "Qualitative Analysis by Spot Tests," 1947, Elsevier Publishing Co., New York, Amsterdam, pp. 86–89.

3 G. Charlot and D. Bézier. (*a*) *Anal. Chim. Acta.*, 1947, **1**, 113; and (*b*) Abstract in *Analyst*, 1948, **73**, 352.

4 Ivar Bang. "Mikromethoden zur Blutuntersuchung," 6th ed., Bergmann, München, 1927, p. 23.

* This gives jets delivering approximately 20 drops of water per millilitre.

few drops of the acid. A flat, clean surface, obtained by using a knife, file or emery paper, can also be used, although the "cup" is particularly suitable. Apply a few drops of the 1 : 1 acid. When the reaction has ceased, transfer one drop from the metal surface to the depression of a spot plate with a dry teat pipette.

Stannous ions are formed by the nascent hydrogen during the reaction, and thus the treatment with iron powder called for in the original method[3] is not required. Unnecessary delay may result in reoxidation of the stannous ions; on the other hand, care should be taken to see that no gas evolution from detached small metal particles persists at this stage, as this will lead to false "positives."

Add one drop of starch-iodine reagent (Solution No. 6) and stir with, for example, a thin glass rod. The reaction is positive if the blue colour disappears within a few seconds. If it is desired to detect small quantities of tin reagent No. 6*a* is used, as reagent No. 6*b* detects only substantial quantities. The quantitative interpretation is discussed below under aluminium alloys.

B. Aluminium Alloys.

The above test has proved reliable on a large number of magnesium alloy samples, the tin content of which was determined by the normal volumetric method[5]: it fails completely, however, with aluminium alloys. In contact with the large excess of metallic aluminium, most of the tin is deposited in the metallic state so that the reaction may be negative, or doubtful, even on alloys containing as much as 30% of tin.

5 See "A.S.T.M. Methods of Chemical Analysis of Metals," 1950, p. 352.

TABLE I

Drops of Metal Solution Required to Discharge the Colour of One Drop of Starch-Iodine Reagent No. 6*a*	Indicated Tin Content %
5	0·05
4	0·10
3	0·2
2	0·3
1	0·5 or more

TABLE II

Charge Number		Alloy Type	Drops of Metal Solution per Drop of Starch-Iodine Reagent	Estimated Tin Content %	Tin Content by Volumetric Analysis %
	117,467	Unknownscrap	11	0·01	0·01
H	9,886	L.A.C. 10	6	0·05	0·02
	6,858	D.T.D. 133C	7	0·05	0·03
	7,868	L.A.C. 112A	6	0·05	0·05
	7,867	L.A.C. 112A	4	0·1	0·08
BP	253	Dross	4	0·1	0·11
	7,866	L.A.C. 112A	3	0·2	0·14
	118,852	Mixed turnings	3	0·2	0·18
TF	6,098	Dross	2	0·3	0·22
P	71,639	Unknown	2	0·3	0·32
TF	6,097	Dross	2	0·3	0·37
TF	5,226	Unknown	1½	0·4	0·40
TF	6,223	Unknown	1*	0·5–1*	0·80

* In this case a further drop of starch-iodine reagent was added after the drop of metal solution had decolorised the first drop of reagent.

The following modified technique is, however, successful. Place 100 mg. of turnings, filings or drillings in a test tube. The time for weighing may be reduced to a matter of seconds by the use of small portable hand dispensing scales*. Add 3 ml. of the 2 : 1 hydrochloric

* Obtainable e.g. from Griffin and Tatlock, Ltd., London, W.C.2, Catalogue Number B12–570, capacity 5 grams.

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Content
olumetric
Analysis
%

0·01
0·02
0·03
0·05
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0·11
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0·18
0·22
0·32
0·37
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